THE JOURNAL
OF THE
ROYAL AERONAUTICAL SOCIETY

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

Edited for the Council by J. LAURENCE PRITCHARD, Fellow

No. 189. SEPTEMBER, 1926. Vol. XXX.

NOTICES

Associate Fellowship Examination

The time-table for Part II. of the Associate Fellowship Examination, which is to be held in the Library at 7, Albemarle Street, on Tuesday, September 21st, will be as follows:—

10.0 a.m. to 1.0 p.m.—Strength and Elasticity of Materials and Theory of Structures.

2.30 p.m. to 5.30 p.m.—Aerodynamics, Mathematics, Chemistry and Metallurgy.

Coventry Branch

A visit to the British Thomson Houston Company Limited took place on August 14th, when a party of fifty members were shown the latest methods of mass production of magnetos and wireless. Mr. A. P. Young gave a short address. The B.T.H. Company kindly supplied tea to the party, and kept all the special machinery running to demonstrate to the members the special items of interest. The whole visit was very well arranged by Mr. A. E. Easthorpe, the Manager.

On the 28th of August a visit was paid to the Whitley Aerodrome. Thanks to Captain Hiscocks, manager of Sir W. G. Armstrong Whitworth Aircraft, the visit proved very enjoyable and interesting. The metal construction of aeroplanes was explained and demonstrated to members and a number of new machines were inspected.

Library

The following books have recently been received and placed on the Library shelves:—Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt, Heft 13; Regulations for Admission to the R.A.F. Cadet College, Cranwell; "Airmen and Aircraft," by H. H. Arnold; "Aerostatics," by E. P. Warner; "Free and Captive Balloons," by R. H. Upson and C. de F. Chandler; "Aircraft Power Plants," by various authors; "Elementary Heat and Heat Engines," by F. G. R. Wilkins; "Deutsche Luftverkehrsstatistik 1925"; Scientific Papers of the Tokyo Institute of Physical and Chemical Research, Nos. 63 to 69, and the Tenth Annual Report of the National Advisory Committee for Aeronautics (U.S.A.), 1924.

Edward Busk Memorial Prize

Members are reminded that the closing date for entering for this prize is September 30th, and the closing date for the receipt of papers is December 31st. The Edward Busk Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes).

Opening Meeting

The inaugural meeting of the Sixty-Second Session of the Society's lectures will take place on Thursday, October 7th, at the Royal Society of Arts, John Street, Adelphi, W.C.2, at 8.30 p.m., when Colonel the Master of Sempill, A.F.C., A.F.R.Ae.S., who becomes Chairman of Council on October 1st for the year 1926-27, will read a paper on "Aero Engine Fuels of To-day and To-morrow."

Lecture Programme

The following programme of lectures has been arranged. Places and times, where not stated, will be announced later.

First Half

Thursday, October 7th.—Colonel the Master of Sempill, A.F.C., Associate Fellow: "Aero Engine Fuels of To-day and To-morrow."

Thursday, October 21st.—Mr. W. R. D. Jones, M.Sc.: "Magnesium Alloys."

Thursday, November 4th, 7.0 p.m.—Joint Meeting with the Institution of Automobile Engineers, at the Royal Society of Arts, 18, John Street, W.C.2. Mr. G. F. Mucklow: "Hydrogen as an Auxiliary Fuel for a Solid Injection Engine."

Thursday, November 18th.—Flight Lieutenant R. S. Capon: "Methods of Performance Testing and Analysis."

Thursday, November 18th.—Major J. S. Buchanan: "The Two-Seater Light Aeroplane Competitions, 1926."

Thursday, December 2nd.—Mr. P. B. Henshaw: "Alloy Steels for Aero Work."

Thursday, December 16th.—Wing Commander C. D. Breeze, A.F.C., R.A.F.: "The Training of Aircraft Apprentices."

Advance Proofs

Advance proofs of all lectures of the coming Session will be forwarded on payment of sixpence each lecture or 2/6 for the first half of the programme for the Session 1926-27.

J. LAURENCE PRITCHARD, *Hon. Secretary.*

OBITUARY

It is with great regret that we have to announce the death of Henry Allan Dalton, an Associate Fellow, who was drowned in a gallant attempt to save the lives of two girls.

Henry Allan Dalton was elected an Associate Fellow in November, 1923, after being for some time a Student Member of the Society. He was educated at the Queen Elizabeth's School, Barnet, Herts, and at the Northampton Polytechnic Institute, where he obtained the Diploma in Aeronautical Engineering.

Born in 1900 he was too young to take part in the Great War, but as soon as possible he became a cadet pilot and served for twelve months, afterwards working in the Airworthiness Department at the R.A.E. He was the official handicapper for the last King's Cup Race.

The Council of the Society offer their sincere sympathy with Mrs. Dalton on the loss she has sustained.

PROCEEDINGS

SPECIAL MEETING, 8TH APRIL, 1926

A special meeting of the Royal Aeronautical Society was held in the Theatre of the Royal Society of Arts, London, on Thursday, April 8th, 1926, when Mr. Handley Page, Fellow, read a paper by Marchese de Pinedo. Air Vice-Marshal Sir Sefton Brancker, K.C.B. (Chairman of the Society), presided.

Sir SEFTON BRANCKER said: Your Excellency, Ladies and Gentlemen,—I think you will all join with me in expressing our extreme regret that Commander de Pinedo has had a very serious illness and so is unable to read his paper himself to-night. Mr. Handley Page has very kindly undertaken to read the paper for him. You will all be very glad to hear that Commander de Pinedo is better and is progressing favourably.

I look upon this great achievement of Commander de Pinedo's as probably the most useful and practical feat ever accomplished in aviation. Others have been perhaps more dramatic and more dangerous, but the voyage of Commander de Pinedo stands out pre-eminent as being of solid value to the world at large. In addition, it is a wonderful demonstration of magnificent piloting, great endurance and tenacity of purpose.

Mr. HANDLEY PAGE, before reading the paper, said: Your Excellency, Ladies and Gentlemen,—I would like to add my regrets to those already expressed by the Chairman that Commander de Pinedo will not be present here to give his lecture himself. I regret it for two reasons; first of all because I, like everyone else, would prefer to hear from the aviator himself the account of his wonderful journey, and secondly because had he been here there would have been no reason for me to read the paper for him.

A FLIGHT OF 33,000 MILES.

BY MARCHESE DE PINEDO.

At the present stage of the development of the different means of aerial flight, we find that there is a greater use of land aircraft than of seaplanes. The most important reason for this arises from the widespread opinion that a larger output of useful transportable weight may be obtained with aeroplanes than with seaplanes. Another reason is that commercial air lines are nearly always run on land, and consequently can better be operated by means of aeroplanes. The use of aeroplanes presents, however, difficulties of a different nature, the chief of which are the following:—

(1) The difficulty of having aerodromes near enough to the centre of large towns, which causes considerable loss of time to passengers leaving or arriving.

(2) Cost of construction and the upkeep of such landing places.

(3) Difficulty and cost of the organisation of emergency landing places along the route.

(4) The difficulty of ensuring the landing, at any one point of the route over a certain fixed emergency camp; and taking into consideration also that the progress in the construction of the engines, together with an intelligent and well-planned organisation, may considerably reduce the possibility of damage which would necessitate an immediate landing.

Let it be remembered, then, that if the system for organising landing places for the permanent operation of a commercial air line is badly carried out, or is lacking as it happens in almost all the inter-Continental air routes, these difficulties are increased to such a degree as to render it prohibitive, if not absolutely impossible, for aeroplanes to fly from one continent to another.

It will have been noticed in the flight round the world carried out by American aviators, and in the flight from England to the Aleutian Isles by MacLaren, how both have found it necessary either to change the type of machine during the journey, substituting floats for the landing gear, or making use of an amphibian. In the first case this meant a serious dislocation of the spare parts during the flight, and in the second case the limiting of the amount of useful load to be carried. The result was the machine was not as strong as it might have been, and it served one purpose only, that is for landing only on the ground or only on water.

It is my opinion that all the above difficulties may be eliminated by means of the use of seaplanes. As a matter of fact, limiting ourselves for the moment to the Continent of Europe, and glancing over the map, it is easy to see :—

(1) That all the most important political and commercial centres of Europe are situated on the coast or on the banks of large rivers or waterways. In either case there are expanses of water where the landing of a seaplane in the vicinity of a large town is not only possible, but usually quite easy.

London, Rome, Paris, Berlin, Vienna, Budapest, Copenhagen, St. Petersburg, Christiania, Stockholm, Constantinople, etc., all of these great towns offer such facilities. The use of the seaplane is therefore advantageous from the point of view of facility for the traveller and also because the goods may be loaded or unloaded at a more central place, both for departure and arrival.

(2) That the routes which connect the most important political and commercial centres of Europe exist mostly in the vicinity of large watercourses or lakes, on to which at any moment it is always possible, as well as easy and practicable, to alight in perfect safety to the machine and to rise again.

What I have said regarding Europe applies also to the whole world, since the most important cities throughout the world owe their rise and their development to the fact that they are to be found in localities where waterway communication with all other great centres of the world is easy. If it were not so, these cities would not have been established.

Aeroplanes must, in the nature of things, have landing stages or large flat spaces well situated as regards the prevailing winds, and well provided with means for carrying away the rain water in such a way that safe and easy landing be ensured. Such spaces, if they happen not to be natural ones, are very difficult to find and very costly, especially near a city where land is in great demand. But any piece of water will serve as a landing place for a seaplane, provided it has the requisite breadth and length and is sheltered. In other words, these landing places must have the same conveniences which harbours for marine transport have, that is, they must be of a good size and in a sheltered position. But they do not require, like marine harbours, a great depth of water. For the largest seaplanes five feet of water at low tide is more than enough.

It may be said, therefore, that there already exist landing places for seaplanes in all the most important centres of the world. They are the natural result of the organisation of many hundreds of years of human labour.

Man has navigated the seas for thousands of years and during that time he has made provision for the safety of the ships which he uses, and spent large sums of money in the construction of dykes and in making harbours.

If man had not learnt how to adopt the principle of Archimedes, and if we had no navigation on the sea to-day and it were necessary to create these stretches

of water for the use of aircraft, then we should require many millions of pounds to construct the ports which we have to-day now ready to hand.

There is in existence, therefore, to-day a most efficient system which provides for the landing of seaplanes such as it is not possible to have of equal efficiency for aeroplanes, at least not for a good many years to come and only at very considerable cost.

Some may object that the traffic of maritime ports, with their ships and boats moving in every direction, is not suitable as a landing-place for seaplanes.

I wish to call your attention to the fact that it is precisely the traffic that there is in the ports that makes landing possible, because traffic means movement, and movement indicates that there may come a moment when a space has to be cleared for landing—say 300-500 yards—which the seaplane requires on arrival or at departure.

This space is only required for a few seconds, because once the machine is floating on the water with the engine throttled down, it may be considered as part of the other seacraft in the harbour.

I am of the opinion that any ordinary pilot can take off again at any time from a harbour that is ever so congested. It is only a matter of regulating and controlling aerial and naval traffic by the same precise rules.

Harbours have also the inestimable advantage of being in the immediate neighbourhood of busy commercial centres or of being in close touch with them.

The same thing may be said about the rivers. Here, on the other hand, the difficulties are less since traffic on a river is generally less intense.

No one will fail to see the great advantage there would be in aerial communication between London and Paris if this were carried on by seaplanes which, starting from Paris at the Concorde Bridge, would land in London in front of Westminster Abbey. At the present time it takes about an hour by motor car to get from the heart of London to the camp at Croydon and the same time to go from the landing stage of Le Bourget into Paris. Thus passengers waste two hours on a journey which should only last two and a half hours.

The journey made recently by myself showed how it is possible to-day to travel round the world in a solidly constructed machine of the seaplane type better than in a small ship, and depending entirely on the local resources. I say better, because with a seaplane it is possible also to navigate on land while it is not so with a ship. Perhaps you will say, " But if by chance some mishap to the engine makes it necessary for the seaplane to land and there is an accident?" I should like to tell you why I do not agree with this by giving you some actual facts.

About two years ago I had to descend in Holland owing to damage to my engine and landed on meadow land. The machine suffered no damage; it was possible to take her on to the water and with the same machine I set off again in flight and returned to Italy over the Alps.

Recently in Italy a three-engined flying boat landed in a small field on the Cape of Gargano without sustaining any damage whatsoever. The seaplane, placed on a carrier, was transported to water and pursued its journey.

I know pupils who are not yet licensed that, through mistakes in manœuvring, had to descend on ground, but they have in most cases done so without causing any great damage to the machine. If you think about it, too, this is only logical.

In a forced landing, I consider an aeroplane more dangerous than a seaplane. As a matter of fact, an aeroplane has as friction surface on landing that of tail skid, which bears about a third of the weight of the machine and perhaps less,

according to the relative position of it to the landing gear, therefore it is not so easy to slow down the landing speed. Now any accident such as the bursting of a tyre, the breaking of the shock absorber of the landing gear, the blocking of a wheel, produces immediately such a sudden brake that on account of the inertia and the moment of the centre of gravity of the machine, it is inevitable that the plane turns turtle, and a somersault of this description does not always have a happy ending.

A flying boat which is landing, slips over the ground by means of the enormous gliding surface formed by the boat. Such surface of contact with the land is much larger than that on an aeroplane and on this rests all the weight of the machine. There is therefore a double reason for a better slowing down of the machine. If then it happens that one part of the boat suffers such damage as to stop the machine suddenly, the following favourable facts must be borne in mind:—

(1) The moment of the centre of gravity of the machine with regard to the ground is much reduced, because there are greater masses and weights below.

(2) If the machine inclines to turn over it automatically brings to the ground the part of the boat which is not yet damaged, and continues to slide on this until it absorbs the remaining force of inertia.

I maintain, therefore, that a somersault by a seaplane is very rare and, if the boat is solidly constructed, absolutely impossible.

The only disadvantage that may be derived in a case of forced landing, well managed, is that the seaplane which has been landed in perfect order cannot take off again, while the aeroplane which lands in perfect order can do so. This is the only difference.

I must repeat, once again, that an aeroplane requires wheels only for taking off, but not for landing. To land it is sufficient to have runners. It is a much safer method and Wright landed his machine by means of skids.

In order that I might give you a convincing demonstration of my theory it was necessary for me to choose a very long flight, and in fact the length of the one planned by me was 33,000 miles, nearly one and a half times the length of the earth's equator, and more by about 7,000 miles than the longest flight made up to the present time.

To prove my theories the route was chosen to run between very diverse regions as regards climate and geographical position. As a matter of fact the journey stretched from 10° to 155° meridian E.G. and from 45° north to 40° south, forming over the earth an immense triangle, the points of which were Rome, Melbourne and Tokio, touching the torrid and temperate zones to north and south of the Equator, crossing the Tropic of Cancer four times and the Tropic of Capricorn twice.

The journey consisted of about 24,000 miles along the coast or in sight of land, 5,000 miles over the open sea and 4,000 miles over dry land. Undoubtedly the most difficult and important problem to be solved was deciding the different points at which to take in supplies. These points had to meet the following requirements:—

They should not be at a greater distance apart than the maximum range of the machine (about 800 miles).

They should have a sheltered sheet of water sufficiently large to alight and take off.

They should have regular communication with the rest of the world so as to be able to send supplies at little cost and without being obliged to charter a steamer especially for the purpose.

They should, where possible, be locally able to provide supplies.

These conditions were studied by me during a period of one month without using any other particulars or information than those given me by the sea pilot of the Navy Hydrographic Office.

It would have been perhaps somewhat more difficult to obtain particulars about rivers inasmuch as there were none to obtain, or at least, if there were, I did not know of any books which described in detail the breadth, the volume of water, the speed of the current and all the other characteristics of rivers on which landing might take place.

The arrangements for my journey therefore came down to this. I had to rely upon what information I could obtain from sea captains of weather conditions and I had to make my own arrangements for sending benzine and oil to all the supply depots.

For the most part on the southern or eastern coasts of the continent of Asia there are from May to September westerly monsoons and from October to March easterly monsoons. In April and in October there is generally a period of calm which lasts about a month.

On the continent of Australia there are from June to September—the winter months—winds which blow right round the coast in the direction contrary to that of the hands of a watch and therefore favourable to a journey which is being taken in the same direction.

In May and June the trade winds are little felt in the Sondian Archipelago.

I found a great obstacle in the bad weather and the rains which prevailed on the east coast of the Gulf of Bengal during the month of May, the beginning of the westerly monsoons.

I decided therefore to fix my departure not later than the first week in April so as to reach that zone before the weather broke up and get to Australia at the beginning of the winter season. Things, however, turned out differently from what I had arranged, and I found myself in Burma in the worst month, very nearly losing my machine there.

I found another drawback in the rains which last from June to October, varying in intensity according to the districts, among the Moluccas, the Philippine Islands and Formosa; also the frequent and violent typhoons which are met with in the zone from the Philippines to Japan in August and September. These typhoons, at their worst in these two months, often blow with winds that attain a speed of 120 miles an hour and sometimes destroy whole villages.

Thinking to reach Melbourne at the end of May and to stay a month there for overhauling the engine, I reckoned to reach my destination in the month of July when the weather ought to be, if not good, at least possible. Instead of this being the case, for various reasons, I found I had to pass this zone of the typhoons just at the most critical period, namely, between the end of August and the beginning of September.

In other words, if I had especially tried to pass the worst season in Burma and the Philippines, I could not have succeeded better. But now that I have gone through it, I am pleased with the experience I have had, which shows that there is no such a thing as weather that makes it impossible for aeroplanes to travel, just as there is not for ships, except of course rare storms of exceptional violence against which there is no defence.

A new course, however, was that from Melbourne to Tokio. While the journey from Europe to Japan had already been achieved before, by the Italian aviator Ferrarin, who was the first, by MacLaren, by Zanni the Argentinian, by Le Pellettier d'Oysy and by the Americans; and while the journey from Europe to Australia had already been carried out by Australian aviators who had flown from London to Melbourne by aeroplane (and in order to study landing places, Smith, as is well known, personally visited by ordinary means various places on

the way); from Melbourne to Tokio no aircraft had ever flown. Moreover, no aeroplane that had the horse-power of the machine I used for the flight would have been able to do it without a very costly and well-planned system of the landing places which do not normally exist in some places.

The machine I used was a service seaplane in the Italian Air Force fitted with a 300 h.p. engine. To obtain a reserve of power, I fitted it with a 450 h.p. engine, the Lorraine Dietrich.

In the beginning of February last year I got one of the machines which had been delivered by this firm to the Royal Air Force and began the work of transformation of the engine support, in order to adjust the 450 h.p. Lorraine to it. In the meantime, the firm of Lorraine tuned two engines of the same power, one of which was to be fitted in the machine on which I was to take off, and the other sent to Tokio to take the place of that used during the first part of the flight.

This seaplane was capable of carrying a useful load of about one ton. I had it fitted with double control, so that the mechanic could take over the steering of the machine when necessary. As a matter of fact, I very rarely passed over the command to him, but it was very useful to know I could do so at a time when it was necessary to ascertain exactly where we were, and when I required to give all my attention to navigating. The machine, moreover, was fitted with sails. These I designed myself, and they gave good results. I could, with a jib fitted between the capstan engine and the prow, and a stout rudder fixed in the boat when needed, succeed in even steering with a contrary wind when the sea was not so rough. It was necessary to make provision for a possible breakdown that might compel me to sail over seas which were not much used by steamers, and where I should not be able to let anyone know of my breakdown. If the state of the sea was not such as to cause me to sink at once, I could continue sailing and reach my destination.

With regard to food, I had a small supply on board, and relied on catching fish or shooting birds to eke that supply out. The greatest problem was that of water, and this was solved with much economy in weight. Instead of carrying a heavy and cumbersome supply, I carried a condenser, which did not weigh more than three pounds, worked by a Primus lamp with benzine, with which it was possible to make in five minutes as much drinking water as can be put in a liqueur glass. Once or twice during the journey I had kind offers of escort, both from Americans and Dutch, but I always refused, feeling quite sure that I could manage by myself.

I had no wireless on board, because it was not worth the extra weight it entailed. Its installation might have been taken into consideration if I had felt sure that I could communicate with the ground stations I wanted to. This was very doubtful, however, and so I gave it up.

I had on board a little portable workshop with everything required for soldering, for carpentering, a little canvas, a little wood, some small spare parts for the engine, a first-rate anchor and a good mooring cable.

My mechanic, fortunately, was an excellent and quick worker, and able to do all kinds of things, and I was well satisfied with him. I think I have now said all that will be of interest to those who are interested in the technical side of the flight.

The journey turned out to be exactly as I had foreseen. I set out from Sesto Calende on April 20th, and the first stage as far as Bagdad passed without any important incidents. I stayed at Brindisi a few days in order to improve some small matters which experience had taught me during the first stage.

The stages from Brindisi-Leros, Leros-Alessandretta, Alessandretta-Bagdad, of about 540 miles each were accomplished respectively on April 23rd, 24th and

25th. At Bagdad I had some difficulty in making a start, because of the strong current of the river, and the same thing at Chahbar, where the machine began to feel the high temperature, which prevented us taking off with a full load.

At Chahbar, in the Indian Ocean, trying to take off in a rough sea, the auxiliary float of the left wing broke, and as there was neither material nor carpenter at hand, the repair took much longer, and forced me to make a stay of five days there. It was necessary also to repair the oil tank, which required soldering, and for which we used an old saucepan, which, with many heart-breakings, we managed to extract from the cook at the English Telegraph Station, where we were hospitably received.

In addition to this, the departure from Bombay was somewhat difficult, because I was obliged to leave with a full load and fly between Bombay and Coconada, a distance of about 720 miles, entirely by land. This distance was very near the limit of the range of the machine, but I had counted on the westerly monsoons, which should have been favourable to me on the way. However, it was not so, for on account of an atmospheric disturbance in the Gulf of Bengal, instead of finding a wind from the west, I found an easterly one, which obliged me to steer towards the mouth of the Godavery to the small place of Rayamundry, not far away from Coconada, where, not having supplies of benzine, I was obliged to feed the tank with a little motor car benzol.

This crossing was made entirely by land. It was not possible to alight on the Godavery, along which river the course was planned, because it was at that time almost dried up. That did not worry me much for the safety of the machine, since I was able to make a good landing, whereas if I had been obliged to come to land I should not have been able to take off again.

The journey continued without any important incidents as far as Akyab. There I had much trouble in taking in supplies, because of the bad weather. At Rangoon I made a short stay, and took advantage to change a valve, the seating of which was slightly bent. The journey from Rangoon to Puket was particularly difficult along the coast of Burma, as the rainy season had already begun, bringing with it the westerly monsoons. Tremendous storms and heavy rains prevented us from getting along as quickly as I had hoped. However, from Puket onward the weather at last began to improve, the rains diminished, and I had smooth travelling as far as Batavia.

At Batavia I made a stay of one day to overhaul thoroughly the engine and the machine, ready for the stages which I had to make along the borders of the desert or on waterways not frequented by steamship lines. The weather at this part of the journey was very favourable. To reach Australia, I headed for Kupang, a Dutch possession in the Island of Timor, straight to Broome with a run of about 550 miles.

In order to regulate the navigation above the sea zone and out of sight of land, I adjusted the compass in flight immediately after taking off, and before starting for the stage to be covered. This correction was made running over a definite straight line parallel exactly to the route and taking the actual bearing of the compass, which I afterwards continued to keep. This method was always very useful to me, and gave me every satisfaction. Navigation was then carried on, keeping the machine at a rather low altitude, in fact the lowest necessary to maintain the radiator at a sufficient temperature for the cooling down of the engine, and also with the aim of being sure of being in a zone in which the winds would differ little from those that predominated on the surface of the water. From the condition of the sea I ascertained the direction and the force of the wind, and corrected the compass for the drift from my own experience. In this way the navigation from Kupang to Broome was carried out in order and without difficulty.

On arrival at Broome I met a doctor who was a surgeon at the frontier

customs house. As soon as we landed, with our shoes in our hands and our hand-bags on our shoulders, being obliged to cross a muddy strip of about 300 yards, we were called on one side by the doctor, who, with a mysterious air, asked me:

"Are you ill?"

"No, Sir."

"And your companion, is he ill?"

"No, Sir, he is also quite well."

"You should have waited before landing until you had obtained a permit to do so."

"Very good, Sir," I replied, "Another time I will carry out your wishes."

Thus the navigation along the coast of Australia went on at fairly good pace, as I was able to continue doing one stage a day from Broome to Melbourne.

I found the coast of Australia very suitable for travelling in a seaplane, both because of the weather conditions, which were generally good, and because of the many seaports which the coast offers at every point of the flight. On the other hand the South Coast of Australia was a dangerous zone, as from Port Albany to Fowler Bay, on account of the desert and the absolute shortage of resources, in case of a landing, there was no way either of getting help or of conveniently repairing the machine.

Fortunately, however, this area was got over without accidents. Israelite Bay was a particularly difficult airport, because it is an open roadstead without any shelter from the sea, although it was the time of the westerly winds, and on this side the bay was protected. We had to work a lot here, because having put the machine on dry land on the shore in order to take supplies, we thought that the next high tide would be of the same strength as that by which we had profited to bring the machine to dry land. But it was lower, and the level of the water did not rise enough to make the machine float.

We were forced to work during the night together with the only four inhabitants of Israelite Bay to get the machine into water.

I arrived at Melbourne on June 9th, that is 50 days after the departure from Italy, and here I stayed five weeks, because as I had arranged, and as I had foreseen, it was necessary to overhaul the engine, and the work was executed in the Australian seaplane station of Point Cook.

In about a week the engine was completely dissembled. The cylinders were in perfect condition, and the valve seatings were in order, except one which gave us some trouble on the journey from Adelaide to Melbourne. The crank-shaft, the bearers of it, and the rods, were, after about 160 hours of flight, in such good condition that it was not considered necessary to dissemble them. The carburettors and the magnetos were put in place as they were before.

The machine was completely overhauled, and found in excellent condition. I only changed the auxiliary floats and a strut, which was slightly bent. I had at Melbourne many spare parts, as rudder elevators, a couple of ailerons, and other things, but I did not change anything, there being no need for it. The controls of the machine were examined and found perfect.

In order not to have to carry too many maps with me, I had not yet prepared the stages from Australia to Japan. I did this work at Melbourne, and the Hydrographic Station of the Australian Navy kindly placed at my disposal all the material which I required. I used nautical maps exclusively, keeping my course almost always on the sea.

In the first week of July the engine was at last ready, and was replaced in the machine, which we took out from the hangar on the 10th of the same month. We then tried out the engine, and found it worked with perfect regularity.

After a brief trial flight, on July 16th, I left Melbourne. A grey cloud soon hid from my sight this magnificent city, which I left most regretfully. Among all the cities I visited during my journey, it is one to which I have a great longing to return.

The run from Melbourne to Tokio was the most difficult part of the journey, because this stage was for the most part over waste pieces of water or along coasts inhabited by uncivilised peoples. Moreover, on account of the delay in the departure from Italy and the stay at Melbourne, which was longer than I had foreseen, I found myself passing over the Philippine Islands during the rainy season, at a time when the typhoons were most frequent. These conditions were made worse by the fact that at Sydney I found something amiss with the engine, which forced me to stay there three weeks to overhaul it again. We had to dismantle the engine, and found bad scoring in nearly all the cylinder blocks, particularly on one. These scores gave the outlet for the oil from the crankcase to the combustion chamber, and the plugs were sparking irregularly. The work was difficult too, because at Sydney there were no hangars, and the seaplane was obliged to be put up on the shore at Rose Bay, and the work was done as best we could under a tent that was put up near the machine.

Fortunately, I had two spare cylinders at Melbourne, which I sent to Sydney, and with one of these I replaced the damaged block. The other I carried on board in case I should want it for exchange. On August 6th I was ready again to set out. I arrived at Sydney the same time as the American fleet, which had come across the Pacific to pay a visit to the Australians, and we left Sydney on the same day, August 6th, in different directions.

In the course along the East Coast of Australia, I had an accident at Brisbane, coming into collision with a tug-boat just when I was preparing to take off. In this collision I suffered some damage to the left float, but fortunately it did not prevent me from continuing my way, and the repair was carried out at Rockhampton. The East Coast of Australia was a really ideal track for seaplanes, because it was much better provided with shelters and coves, which was not the case on the West Coast.

From Thursday Island, I crossed the Torres Strait near Merauke, a small village on the south coast of New Guinea, inhabited by the tribe of the Kaia-Kaia, formerly cannibals, and by a Dutch Mission. These Kaia-Kaia had never seen an aeroplane, and they would not believe the missionaries, who had told them of my coming some time before. Great was their emotion and astonishment when they saw my machine appear in the sky at Merauke. These natives are in a very low state of civilisation, in fact, it may be said that they are at the Stone Age, and it is only due to the influence of the white man that they have thrown off their habits of eating human flesh.

From Merauke onwards there were four successive stages to Dobo, Amboina, Menado and Zamboanga in the Island of Manilla, which at distances varying from 400 to 500 miles, took place over the open sea and away from any line of navigation whatever. There, too, the only means of communication was in the form of a mail boat, which goes once a month to the most important places in the Molucca Islands.

At Zamboanga the difficulties began. Zamboanga was one of the few places during my journey where the machine was obliged to land on the open sea. It was a very difficult take-off leaving Zamboanga, because of the bad state of the sea and because of the strong wind caused by the typhoons which, almost without interruption, arising round the Island of Guam, pass northward of the Philippine Islands and into the Balintang Canal.

At Cebu, which was my next point, a storm stripped the mooring from the aircraft shortly after having landed, and the machine drifted over an oyster bed

and then under the stern of a steamer, and sustained some damage that was fortunately of little consequence, and quickly repaired.

In consequence of the extreme heat and the lessened compression of the engine and the take-off being difficult, I reduced the quantity of petrol so that I should have only a small surplus to provide for the length of the different stages yet to come. I suffered some inconvenience, because leaving Cebu for Manilla with the limited supply of petrol, I encountered, on account of a typhoon which was then passing to the north of Luzon, a very strong wind from the west, and therefore almost contrary to the course, and the intensity of which variated between 30 and 50 miles an hour. On that same morning on which I set out from Cebu, the sea was so stormy that the mail boats were obliged to take refuge in port.

Fearing that I might finish the petrol before arriving, I was obliged to change my course so as to be able to steer to a sheltered spot very near Manilla.

So it happened that I landed in the little bay of Atimon in the Island of Luzon, where I had several mishaps, among which was an unexpected bath, the boat which carried me in search of benzine becoming immersed. I made several attempts to pass that day by the side of the Island of Luzon near Manilla, but I was obliged to give it up on account of the state of the weather.

The engine, on account of its being overheated due to the unsuccessful attempts at taking-off, had pitted the valve seatings. So I passed some time at Atimonan, and after about three days, I was able to take flight for Manilla, where it was necessary to carry out a complete overhauling of the engine, which took about another three weeks.

On September 16th I was able to leave Manilla and resume my journey. I flew to Aparri and from here to Tam-sui to the north of the island of Formosa. This course was one of the most dangerous, because it crossed the canals of Balintang and Bashi, where we encountered rains and typhoons, and along the east coast of Formosa, which is deprived of any shelter whatever, and inhabited by a savage tribe.

It would have been preferable to pass over the east coast of Formosa, but the Japanese would not give me permission for military reasons. I had a small diplomatic question to settle on arrival at Tam-sui, because, during the last part of the course, in consequence of the clouds and weather conditions, I had not complied with the wishes of the Japanese, who desired me to cross the island from the east to west below the extreme north point, which was prohibited to aeroplanes. Instead, I had continued my way along the coast, not being able to cross overland because of the state of the weather.

After Tam-sui I was able to get to Tokio quickly, taking the route via Shanghai, Mokpo to the south of the Korea, Kagoshima, and Kushimoto. I still had bad weather on my arrival at Kagoshima. I arrived at Tokio in my seaplane from Kasumigaura on September 26th in a sudden storm.

So the second and most difficult part of the journey was accomplished. At Tokio I had a stay of three weeks, during which time I arranged, in accordance with my plan, for the changing of the engine. The machine was in splendid condition. By way of precaution, I changed the lower right wing, the one that had suffered the most by the various collisions I had had during the voyage. The wood of the hull and the canvas of the wings were in perfect order, notwithstanding the fact that the machine had been almost always in water and exposed both to the persistent rains and the damp and humid climates nearly the whole of the flight.

On the 17th of October I was ready to set out and on that day I left the seaplane at Kasumigaura and went to Kagoshima. The following day I flew direct from Kagoshima to Shanghai across the China Sea. It was a course of 750 miles on the open sea. On the 18th of October I flew from Shanghai to Hongkong, staying a few hours at Amoy to take in fresh supplies for the machine.

Then I headed for Haiphong. From Haiphong I had arranged to go direct to Bangkok across Cochin China, but it was the rainy season there, and leaving in that direction, I could not pursue my journey on account of the bad weather. I had arranged to take supplies also on the coast, and therefore when I saw that I could not pass on the upper counterfort of Cochin China on account of the rain and the clouds, I reached the coast and continued the course along it, stopping at Tourane for supplies and reaching Saigon the same day.

The following day, the 22nd of October, I went from Saigon to Bangkok, cutting across Cochin China. Here I had rather bad weather. At Bangkok I had to make an unexpected stay of four days, during which time I proceeded to repair a magneto which showed a short circuit in the brushes of the commutators, and having repaired this took flight again over Rangoon and Akjab and reached Calcutta on the 28th.

This time, having now obtained precise information about the rivers of North India, instead of following the course from Cocananda to Bombay, I followed that of the north, namely, Benares, Delhi, Bawalpur and Karachi. I glided to Benares on the Ganges and on the following day over the Jumna to Delhi. The course there was very convenient for seaplanes, as on the large rivers Ganges and Jumna, especially in the season that I passed there, it was possible to land anywhere safely. From Delhi I went to Bawalpur, crossing the desert, and from Bawalpur, after a short delay for supplies, I set out the same day for Karachi, where I arrived during the night, but it was full moon and the landing was made in order.

On the return, instead of Chahbar, I stayed at Guadar, which being on a rather long and narrow promontory, and standing out well from the coast, has the advantage of Chahbar in permitting the landing both with westerly winds as well as easterly ones, whilst Chahbar is exposed to the westerly winds.

Soon after I left Guadar I ran into a seagull. Fortunately the bird did not get into the propeller, otherwise it would have been necessary to make a long halt.

The journey went well as far as Italy. From Bender Abbas to Taranto was a distance of about 3,000 miles. I was able to travel quickly, accomplishing the two stages, Bender Abbas-Bushire and Bushire-Bagdad on the 3rd of November, from Bagdad to Alessandretta on the 4th and Alessandretta Leros, Leros Taranto on the 5th. In order to be able to do the last two stages in one day, I was obliged to leave Alessandretta at night.

On the 6th I arrived at Naples and on the 7th at Rome where, gliding over the Tiber, I ended my cruise. The return was more tiring, because on account of the taking in of supplies and the mooring we were able to sleep very little, and on an average not more than four hours a day. The supplies of petrol, made by the Shell Co., were carried out excellently everywhere.

Summing up, the first zone of the run from Sesto Calende to Melbourne, the total distance of 14,000 miles was accomplished in 160 hours of flying and 50 days of time. During this run the 'plane remained almost always, with the exception of three days in Rangoon and one day at Batavia, moored on water. The hull and the wings resisted splendidly without requiring any alteration, notwithstanding the heat which at Bombay and in the other countries in India reached more than 100° Fahrenheit, and in spite of the continual downpour of rain in Siam.

The second zone on the route, from Melbourne to Tokio, was 8,000 miles long. This, as I have already said, was the most difficult part of the flight, both on account of the weather conditions, the inhospitable regions and vast stretches of water that we came across and because the engine had already flown for 160 hours.

The 8,000 miles were flown in about 90 hours, in 70 days of time if we reckon the run from Melbourne, and in 50 days calculating from Sydney.

The third zone of the flight from Tokio to Rome was 11,500 miles and was accomplished in 110 hours and 21 days of time. This time can clearly be considerably shortened with a more powerful machine. The low power of our 'plane forced us to make numerous landings, which meant much fatigue for us and a great loss of time in taking supplies. Moreover, this voyage was very exhausting for us, for as I have said, we did not manage to sleep for more than four hours a day. More than once I achieved two stages in one day, as, for example, from Shanghai to Hong Kong, 900 miles, from Haiphong to Saigon, 900 miles, from Delhi to Karachi, 1,000 miles, from Bender Abbas to Taranto, a run of 2,700 miles in two days and a half, flying thirty hours at different times and sleeping in all not more than 10 hours. However, our health did not suffer at all, and I arrived at Rome in a fit condition and ready to start all over again.

I hope that the voyage accomplished by me may be a guide for those who are in air forces all over the world, especially with regard to the question of the greater practicability of seaplanes than aeroplanes in great aerial trans-continental communication, not to mention that of general international communications.

I see in the future large and powerful 'planes that are suitable also for navigating on water by means of sails. For their practical use, nothing else is necessary than that of establishing piers in the small harbours which will simplify their being anchored and give facilities for landing and embarking the passengers.

The longest voyage that can be taken on land or of going from any one place to its antipodes, may be then accomplished in about four days.

When that is so, the world will seem small and narrow. The problem of rapid aerial international communication awaits solution during the present generation. In generations to come we shall perhaps solve that of interplanetary communication. With the aid of astronomy, we shall be able to study the ways, and with projectiles we shall be able to open the paths leading to them. That is how mankind can increase his power and extend his civilisation to the other habitable planets of the solar system.

At the conclusion of the lecture, Sir SEFTON BRANCKER said: I agree very cordially with a good deal that Commander de Pinedo has said about the use of the flying boat and the seaplane. I am rather ashamed of the fact that the development of marine aircraft has not progressed as I feel it should in this country. To-day, Italy is probably leading the world in the operation of marine aircraft and Commander de Pinedo is well qualified to speak as he has. It is a curious fact that the average pilot seems reluctant to fly across land in a flying boat when he thinks nothing of flying across the Channel in an aeroplane. Actually, it is quite as safe and easy to make a forced landing on land with a boat or seaplane as with an aeroplane, whereas a forced landing with an aeroplane in the sea is bound to lead to trouble.

Commander de Pinedo is obviously a man of great initiative and enterprise. His expedients of carrying sails and a water condenser are most interesting. I think also when we hear his comments on interplanetary air communication we must admit he is a man of considerable imagination. His statement almost inspires me to draw up a specification of an aircraft to reach our nearest planet.

Finally, Your Excellency, I trust that you will convey to your Government our profound admiration of Commander de Pinedo's great achievement and to express our gratitude to him for letting us hear his paper to-day, and wish him a very speedy recovery.

PROCEEDINGS

SEVENTH MEETING, SECOND HALF, 61ST SESSION

A meeting of the Society was held in the rooms of the Royal Society of Arts, John Street, Adelphi, London, W.C.2, on Thursday, April 22nd, when a paper on " The Tailless Aeroplane " was read by Captain G. T. R. Hill. The paper was illustrated by lantern slides and cinematograph films. Major-General Sir Sefton Brancker (Director-General of Civil Aviation) presided.

The Chairman said it was a real pleasure to him to introduce Captain Hill to the meeting, because he was one of the type which could do more for the general progress of aeronautical design than any other, being a man with great scientific attainments and with very wide practical experience. He designed his own machines, constructed them and flew them, and such a combination always produced very good results.

Captain Hill then read his paper.

THE TAILLESS AEROPLANE

PART I.—PRELIMINARY INVESTIGATION.

1 *Introduction*

This is the first occasion on which I am able to make public the results of one of the pieces of research work on which I have been engaged during the past three years; it therefore seems to be an opportune moment for placing on record, side by side with the results, the forms of assistance to me which enabled those results to be obtained. I am anxious to do this as I have been ploughing a lonely furrow, and I would like to see the kind of help which I have received widely extended, so that the vast field of research may soon be scored by a number of single furrows; if the powers that be are far-sighted enough to give this help, I believe that from these furrows will spring a harvest of no small value, even when compared with the products of the great Government and trade efforts.

I am therefore presenting this paper in the form of a connected story, with the discussion of technical questions interwoven with the account of how and when those questions arose. The method of attacking the problems I met depended so largely on the facilities I had at command that any separation of the technical arguments from the history of the enterprise might cause the reader to lose sight of the close relation between the two.

For three years I held a Studentship awarded by the Royal Commission for the 1851 Exhibition, and in the seclusion of a little country cottage I was able to think about anything I liked without being worried for my results at the end of the week.

2 *Object of the Enquiry*

I thought about safety in flight, in particular about what may be termed " aerodynamic safety," by which I mean the freedom from accident caused through lack of control. Being faced with the fact that about fifty lives were being, and I believe are still being, lost in the Royal Air Force every year, and that a large proportion of the accidents are due to a loss of control in the air,

I set myself to try to design an aeroplane which would never, through an error on the part of the pilot, get out of control; and this paper describes the result of my conception, design and construction.

3 *Basic Principle*

I believe that it was in large measure due to my position of detachment, my freedom from the urgency of having to produce a new idea of some sort for to-morrow's use, that I was enabled to sit down for a while in front of basic principles. I think it will be of interest to state those principles, and the arguments founded on them which led to the clean break which I made from conventional design.

I confess that at that time I had rather lost touch with the simple conception of the forces acting on an aeroplane in steady straight flight as consisting in essence of the weight acting downwards through the centre of gravity, and the total air force acting vertically upwards through the same point. Putting aside for the moment all consideration of rotation about a vertical axis which will be dealt with later, an aeroplane may be considered to consist of one or more lifting surfaces which provide that the vertical component of the air forces may oppose the weight, and an engine-driven propeller to secure a zero resultant horizontal force without the need for a downwardly inclined flight path.

In order to trim at different speeds, the total air force must pass through the centre of gravity at more than one attitude. Imagining for simplicity that the centre of gravity is on the wing chord, and taking the centre of pressure in this argument to be not the centre of pressure of the wings alone, but that of the whole aeroplane after the elevators have been set to the required angle for trim, we see that the centre of pressure must not vary with attitude if the aeroplane is to have any speed range. This is the fundamental requirement on which I want to focus attention. So long as the centre of pressure is stationary, just so long will the aeroplane fly steadily.

4 *Functions of Aeroplane Controls*

Control surfaces fitted to an aeroplane perform four duties:—

(i.) To trim the aeroplane at different speeds. Each speed requires its own particular setting of the control surfaces to ensure that the centre of pressure coincides with the centre of gravity.
(ii.) To trim with different load distribution.
(iii.) To correct disturbances due to wind gusts.
(iv.) To secure the power of manœuvring.

Dealing with the last duty first, it is surprising to find how small a shift of centre of pressure is required for manœuvring. Take an aeroplane of the size of the Bristol Fighter as an example; I estimate roughly that a movement of the centre of pressure of 3in. fore and aft or 6in. laterally is sufficient for all ordinary manœuvres, and double these movements will suffice for the most rapid manœuvres. The 3in. and 6in. centre of pressure movements are obtained if the elevator or ailerons are instantaneously moved through 1° at top speed or 5° at stalling speed. This is not to say that 1° control movement at top speed is sufficient to carry out the manœuvre, for as soon as the aeroplane starts to rotate, the centre of pressure moves quickly back towards the centre of gravity, and in consequence the angular acceleration falls rapidly off, and the aeroplane tends towards a new condition of trim at a certain rate of rotation, with the centre of pressure again coincident with the centre of gravity.

From the magnitude of the maximum control movements which we find in practice, it is evident that the movement is required more for the purpose of trimming the aeroplane when rotating than for producing angular acceleration.

We may now usefully regroup the functions of the controls, and say that they are:—

(i.) To trim the aeroplane at different speeds in straight flight, and at rates of rotation up to the maximum required for manœuvring.
(ii.) To trim with different load distribution.
(iii.) To correct disturbances due to wind gusts.
(iv.) To produce angular acceleration.

There seems to be little difficulty in dealing with the last three functions of the controls. Correction for varying load distribution must be watched, but it can almost invariably be secured without trouble. I think it will be agreed that if a good rate of manœuvring is attainable, no trouble will be experienced with wind gusts, except where there exists great instability. The small control movements to produce the necessary angular accelerations have been referred to above.

Thus I hold that the problem of control really resolves itself into the search for the stationary centre of pressure throughout the range of straight flight and rate of manœuvre required; and in addition, the avoidance of gross instability.

5 *Power of Normal Controls*

Let us now examine how well, or ill, we are served by the controls fitted to the normal aeroplane; for convenience the whole control system may be divided into its three components—longitudinal, lateral and directional.

The examination would be comparatively easy if only the operation of the longitudinal control simply pitched the aeroplane, the lateral control banked and the rudder control yawed it. The controls of the normal aeroplane, however, have something in common with the Irish; they like, on occasion, to do someone else's job to the neglect of their own; this is asking for trouble, and as we know to our cost, getting it.

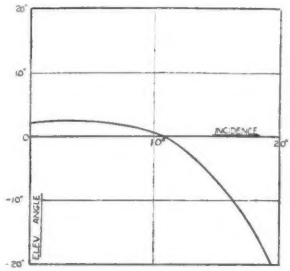


FIG. 1.
Bristol Fighter.
Elevator Angles Gliding.

(i.) *Longitudinal.*—Fig. 1 shows a typical example of the variation of elevator angle with incidence; it refers to a Bristol Fighter when gliding, and it will be remarked that at 19° incidence, just beyond stalling point, the full limit of the control has been reached; and while there is a good margin of control at all normal speeds, say down to 52 m.p.h. which is about 14° incidence, yet as we go below this speed, the whole of the available control is used up in maintaining trim. Thus the range of possible attitudes for steady flight is strictly limited, and should for some reason the aeroplane become stalled, the elevator control will be ineffective; in other words, the aeroplane will be out of control.

(ii.) *Lateral.*—Apart from counteracting the engine torque, which is small, no portion of the lateral control is eaten into by the requirements of trim. The

next question therefore is—how much control is required for maintaining the rates of roll, yaw and sideslip which constitute "good manœuvrability"? Fig. 2 indicates the rates of rotation and sideslip, in a non-dimensional form, which may be expected from the normal control system if a straight flight can be maintained, as is the case below the stalling angle. Confining ourselves at first to this range of angles below stalling, we know from practical flying experience that an aeroplane having the characteristics shown in Fig. 2 is under good control, and we may therefore co-ordinate the test results with common language by saying that motions represented by the diagrams constitute "good manœuvrability."

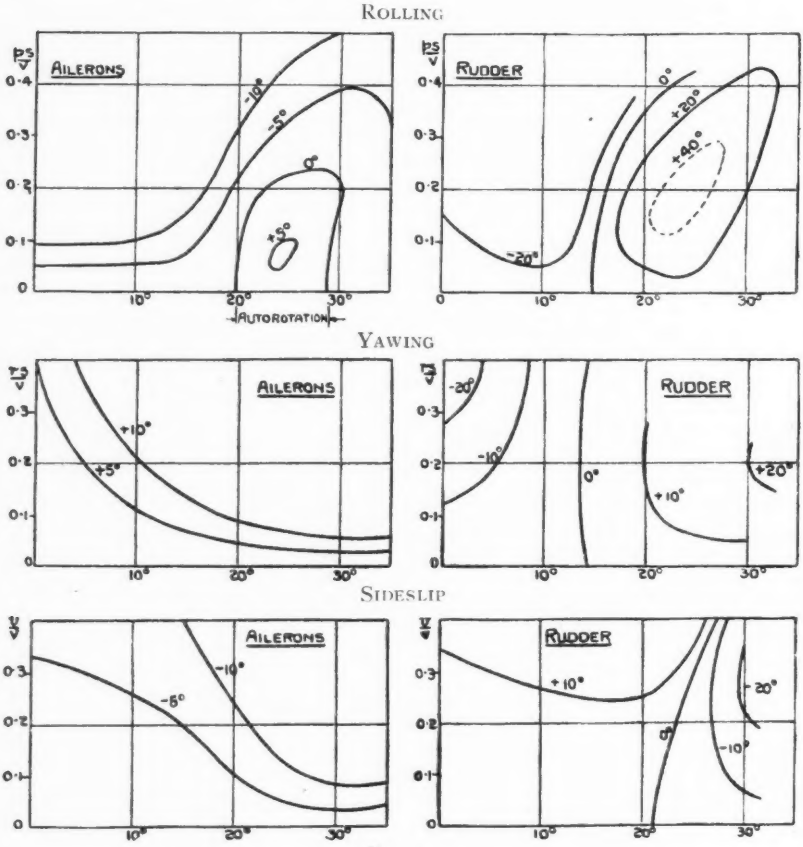


FIG. 2.

Lateral Control of Aeroplanes of Conventional Type.

Proceeding now to a consideration of the motion at and after stalling, we are faced with the more complex state of affairs due to the interaction of the lateral and directional controls, which now may render straight flight, the basis on which the diagrams in Fig. 2 are founded, impossible. This interaction of the controls is fairly clearly understood and arises from the fact that the normal type of ailerons, when set over to produce a rolling couple, also produce a yawing couple; if this yawing couple cannot be neutralised by the rudder, then the

aeroplane will yaw, and its act of yawing will tend to roll it against the ailerons. At normal angles of incidence, *i.e.*, well below stalling point, the tendency to yaw is small and causes no trouble, but near and beyond stalling the undesirable yawing couple produced by the ailerons is so large as to overcome anything which the rudder can cope with, with the result that the ailerons are ineffective as an organ of control.

(iii.) *Directional.*—A small rudder angle is usually required to maintain straight flight. The reason for this is that the rotation in the propeller slipstream causes a lateral force on the fin, and the turning tendency thus produced must be counteracted by setting the rudder across. Fig. 3 shows the angles

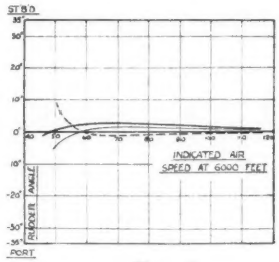


FIG. 3.
Bristol Fighter Rudder Angles.
Full Throttle ——
Half Throttle ———
Gliding — — —

required on a Bristol Fighter under different conditions, and it will be seen that they are small compared with the maximum rudder angle, which is 35°. Thus, as with the lateral control, so we find with the directional control, that nearly all is available for the maintenance of definite rates of roll, yaw and sideslip. The required rudder angles for a normal aeroplane are shown graphically in Fig. 2.

As before, we will first examine that part of the diagrams below the stalling angle. It will be seen that the rates of motion described above as "good manœuvrability" are within the capacity of the rudder, and the control is satisfactory. Above stalling, however, there is a large region between 20° and 30° incidence in which is required a rudder angle greater than the maximum of 35°. This of course means that the rudder control provided is insufficient to maintain straight flight when rolling.

(iv.) *Influence of Stability on Control.*—No discussion of the control of an aeroplane would be complete without some reference to the influence of stability on the margin of control which is required for safety. No one has yet succeeded in putting this subject on a quantitative basis, thus we are thrown back to a more general survey; perhaps the best plan is to concentrate at first on the most important aspect of the problem, viz., the lateral instability which occurs after stalling, including the phenomenon of autorotation. On reference to Fig. 2 it will be seen that between 20° and 30° incidence for 0° aileron angle there are two possible values for the rate of roll, and the zero value, *i.e.*, straight flight, is an unstable value. The instability in flight associated with this condition is most violent, and I suggest that it is when in this state of instability that wind gusts are responsible for their most evil effects. It is a notorious fact that normal aeroplanes which can be flown stalled with fair success in dead calm air become uncontrollable when stalled in bumps. One lesson to be learnt from this is

that *ceteris paribus*, more powerful controls must be provided where there is instability, but the more useful deduction is that it is better, if possible, to avoid the instability.

(v.) *Summary.*—Summing up, we are faced with the conclusion that while the controls of a normal type of aeroplane are adequate so long as the stalling angle is not approached, they all become ineffective in stalled flight, while at the same time serious lateral instability develops.

I have thought it worth while to give in detail the grounds for this conclusion, since many people are yet unconvinced that we really want anything much better than the present-day aeroplane, which they see flying every day apparently under perfect control. Then, fully appreciating the shortcomings inherent in all present-day design, a close examination of the arguments presented above will give the key to the why and wherefore of the tailless design about to be described.

6 *Evolution of the Tailless Design*

(i.) *Wing Shape.*—I started off with the idea of a wing which would have a stationary centre of pressure. To secure this, there are two possible modifications to what may be called the normal wing with its large centre of pressure movement; one consists in reflexing upwards the trailing edge of a rectangular wing, and the other consists in sweeping back the wing-tips and washing out the incidence progressively towards the tip. It must not be forgotten that when I was engaged on the first design, more than three years ago, much less was known about wing sections with stationary centres of pressure than is known now; and it appeared to me then from an examination of the available data that the loss of maximum lift and L/D in attaining the desired result would be less with the swept back wing than with the reflexed straight wing.

A swept back wing was therefore chosen and a 5° washout in incidence to the tip was calculated, on the old strip theory, to secure a stationary centre of pressure. Movable extensions were provided to the tips of the wings for control purposes; I have called them "controllers," as when operated simultaneously they act as elevators and differentially as ailerons; they are therefore the equivalent of these two controls. The wing was heavily tapered in plan form, mainly to reduce the chord of the controllers. Tapering is beneficial from every point of view except that of production; it reduces the air damping and inertia about a longitudinal axis by about a third, and it also reduces the structure weight as there is less bending moment on the wing truss at the centre; again it is slightly superior aerodynamically to the rectangular plan form. I know that production engineers will hold up their hands in horror at the idea of tapered wings, but it is interesting to note, besides the old parallel with the shape of high speed boats, how the Zeppelins have dropped the cylindrical for the true streamline form. In so new a branch of engineering as aeronautics construction must always serve rather than rule.

(ii.) *Controllers.*—If the centre of pressure of the wing is stationary, and at the centre of gravity, the position of the controllers for trim at each incidence will be along wind. They will have no force on them in straight flight, and will have their full angular range, from no lift to maximum lift, both up and down, available for purposes of control. It has been found, see §2, Part II., that this ideal can be nearly realised over a surprisingly large range of incidence; in this range the centre of pressure of the wings lies about 0.3 chords behind the leading edge of the mean chord, and after stalling it moves steadily back to the middle of the plane when broadside to the wind.

The discovery that the controllers when used differentially for lateral control could start their differential movement from nearly no lift brought to light the valuable characteristic of small ratio of yawing moment to rolling moment which had been achieved. It will be remembered that conventional ailerons become ineffective after stalling for lack of this characteristic.

In the original design, flaps were fitted to the trailing edges of the controllers, as the calculations showed that with a differential movement of the controllers as a whole, the fore and aft force on the stick would vary, although the mean angle of the controllers was unaltered; the use of flaps moved differentially for lateral control seemed to avoid this trouble. The calculations of course neglected all interference, and subsequent model tests showed that the simpler method of moving the whole surfaces differentially did not in fact lead to the difficulties anticipated; flaps were therefore dispensed with in the actual machine, to the great simplification of the control system.

It will be seen that, in virtue of their position, the controllers when held fixed, tend always to damp rolling motion, both when the main wing is stalled as well as unstalled, since the controllers are not themselves stalled. Thus the serious instability which gives rise to autorotation is avoided.

I proposed that for experimental purposes really large control surfaces should be fitted, and designed them to have one quarter of the wing area. It is easier to cut down control power than to increase it.

(iii.) *Rudders.*—In order to produce yawing, vertical surfaces, which I still call rudders, were to be mounted above and below the extremity of the fixed part of the wing, on its rear spar. These surfaces were arranged to be "single-acting," *i.e.*, the surfaces on one wing only were moved outwards at their trailing edges to produce a yawing moment. The force on the surface acts approximately at right angles to it, and as the surfaces are turned, the force on them increases and its line of action passes progressively further from the centre of gravity; thus the moment produced builds up increasingly rapidly, and large rudder angles of over 45° can be used effectively.

(iv.) *Performance.*—The loss of maximum lift and L/D with this arrangement of wings and control surfaces was estimated and found to be small. To counterbalance, and possibly outweigh this loss, a reduction in structure weight was anticipated.

(v.) *Report to A.R.C.*—I described my proposals fully in a report to the Aeronautical Research Committee in the spring of 1923, and suggested that a full-sized glider should be built to try out my ideas in actual flight. I regarded my design as a natural development from old-time tailless aeroplanes, among which that designed by Lieut. J. W. Dunne achieved the greatest measure of success. In respect of stability, I believe that his aeroplane was ahead of all others built before or since. It is a difficult problem to know how far it is wise to go in copying Nature, but my design certainly seemed to resemble more nearly than the conventional type of aeroplane the most efficient gliding birds, such as the gulls with their small tails, or the tailless pterodactyls which are said to have been capable of several hundred miles flight at a stretch.

Part II.—Experimental Work

1 *Start of Full-Scale Work*

I was so encouraged by the neat dovetailing of the different features, each essential for its own duty, into a harmonious whole, and the advantages to be gained from a tailless design were so clear to me, that with the backing of a friend, I decided to start straight away on my own, and design and build in my back garden a tailless light aeroplane to put my ideas to the test.

To simplify both construction and comparison with my calculations, I decided to build a monoplane, which I designed with a semi-cantilever bracing for rigidity, and a very light wing loading to reduce the risk in case of a crash; I even went one step further in my policy of "safety first" by planning to make the initial air trials without the engine as a glider. A special centre section was designed for the gliding trials with the pilot's seat adjusted so as to secure the desired position of the centre of gravity. The wing area was 223 sq. ft., and the

loading for the glider worked out at 1.85lbs. per sq. ft., giving a landing speed of a little over 20 m.p.h. As the whole wing structure was designed to carry a total weight of double that of the glider, any structural failure was most unlikely. I thought that the gliding trials would provide an opportunity to test the behaviour of the short undercarriage when taxying. I was more anxious about this feature than about any other, largely because it was not comparable with previous experience of recent times, nor was it amenable to any but the most tentative theoretical investigation. Another advantage of gliding before flying lay in the earlier date at which the first trials in the air could be made; the benefits which flowed in immediately after the gliding proved the wisdom of this policy, apart from its " aerodynamical " soundness.

2 *Wind Channel Tests*

After I had started the design, the Aeronautical Research Committee came to the conclusion as the result of my report to them that there was enough promise in my ideas to justify model tests, which they proceeded to carry out for me at the Royal Aircraft Establishment without delay. Thus the design and construction of the aeroplane, and the model tests all went forward together hand in hand, and the design was modified in the light of the model tests where it was found desirable. The modifications were fortunately not far-reaching, and were capable of incorporation in the design without scrapping anything that had been made; they consisted in

(i.) An alteration in wing section by reflexing up the trailing edge to reduce the moment at no lift, and by reducing the camber towards the tips to prevent a sharp drop of lift after stalling producing autorotation.

(ii.) A small shift of the hinge position of the controller to improve the balance.

(iii.) The placing of the whole of the rudder area below the wing, owing to the loss of power of the rudder above the wing after stalling.

(iv.) The operation of the controllers differentially for lateral control, as referred to in Part I., § 6 (ii.).

(v.) The fitting of small fins at the wing-tips.

There are three points of outstanding interest in the model tests. First, it may be observed from Fig. 4 how very closely the controllers lie along wind at all incidences between 0° and 30°; in other words, how nearly stationary is the centre

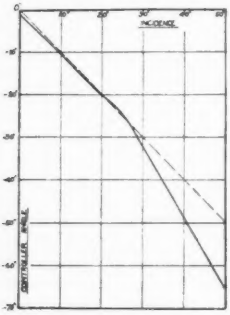


FIG. 4.
Pterodactyl Model. Controller Angles for Trim.

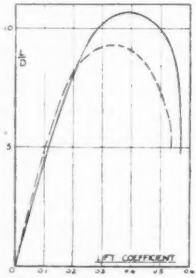


FIG. 5.
Pterodactyl Model. Lift/Drag.
Complete with Controllers ——
Without Controllers - - -

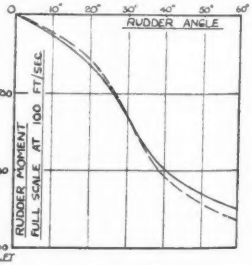


FIG. 6.
Pterodactyl Model. Rudder Moments—
5° Incidence ——
40° Incidence — — —

of pressure. Secondly, the surprising effect of the controllers on wing efficiency. The two curves in Fig. 5 show L/D plotted against lift coefficient for the model tested without controllers, and with controllers set to trim; the maximum L/D is 15 per cent. better with controllers than without. It is interesting to note that the values of L/D with controllers can be found from the tests without controllers by simply applying the Prandtl correction for aspect ratio, and allowing for the extra drag of the additional surface; why this should be so when the controllers lie along wind, and do not form, as regards lift, a continuation of the lifting wing is not clear. Lastly, the manner in which the rudder yawing moments do not fall off in the normal way with increase of incidence. It will be seen from Fig. 6 that even at 40° incidence the rudder is more powerful than at 5°. If the force on the rudder be assumed to act perpendicularly to its surface, the maximum yawing moment corresponds to a force coefficient of 0.8, which shows that about half the yawing moment is due to interference between the rudder and wing, with the interference, most unusually, increasing instead of decreasing the desired effect.

3 *Conversion to Two-Seater*

During the winter 1923-4, I came to the conclusion, as the result of discussion with the Airworthiness Department of the Air Ministry, that I was making the structure unnecessarily strong, and that with slight modification it would be possible to carry a passenger. About the same time the Aeronautical Research Committee decided, in view of the successful progress of the model tests, to help me with grants of money towards my out-of-pocket expenses in connection with the full-scale machine. I therefore continued the design and construction as a two-seater with the improvements and refinements that the backing of the A.R.C. encouraged me to make.

4 *Gliding Trials*

The aeroplane arranged as a glider was completed in December, 1924, and was tried in a remote spot in the South Downs where, just twelve years before, my brother and I had done some gliding on a glider which we had built. The farmer, Mr. Collinson, did all he could to help us, nevertheless the expedition was carried out under great difficulties owing to the time of the year, which was an exceptionally stormy one. The tent in which the glider was housed was in the last stages of decay, and needed constant attention day and night to keep it standing at all. For this reason the gliding tests were cut down to the minimum.

The first glide was made on December 13th in Devil's Rest Bottom. A catapult, or elastic tow-rope, was used for launching, and against a 12 to 15 m.p.h. wind the glider got off the ground after a run of about 10 yards. In the excitement of the moment I forgot to pull the " quick release " letting go the tow-rope, which consequently began to pull backwards soon after the start, thus bringing the glide to a premature conclusion; however, I was able to make a successful landing after gliding about 150 yards.

The main object of the gliding trials had now been attained; I had satisfied myself that the control system was effective, and that the aeroplane would be safe to fly under engine power. I made three more glides, the longest being 300 yards, and nearly ending in disaster to the machine owing to the unexpected flatness of the gliding angle; I was carried up close to a fence at the foot of the hill which I had thought was far out of possible range. The measured gliding angle on this and on the next flight was 1 in 11. On another occasion, a false start, caused by my slipping the tow-rope before I was properly in the air, gave the undercarriage a chance of demonstrating its qualities, as the glider taxied about 100 yards down the hill over some rough ground without any trouble. At the end of the fourth glide, during which the glider seemed practically out of control, one of the control operating tubes was found to be badly buckled, probably

by one of the unskilled handling party; as repairs would have taken a day or so, the camp was then broken up. The machine was dismantled immediately and stored for safety in a garage of a country house belonging to Mr. Pirie, who showed the greatest kindness to all of us, and whose assistance in many ways proved invaluable.

I returned from the gliding trials with a great sense of satisfaction that no alterations in design were necessary; I had hardly dared to dream that such a miracle could really come to pass.

5 *Installation of Engine*

The success of the gliding trials rapidly bore fruit. Further assistance was offered to me by the Air Ministry, who authorised the loan to me of a draughtsman and a fitter from the R.A.E. to expedite the design and construction of the body, and the installation of the engine, a Bristol Cherub. I was also enabled to get such parts as steel sockets and fittings made at the R.A.E., and of course I had had from the beginning the benefit of advice from them on every imaginable subject in connection with the work, from the degree of dope tension required to the insurance of the machine. I think that many people have no conception of the vast storehouses of information, so freely and willingly given to me, behind the letters " R.A.E."

6 *Detailed Description of the Aeroplane*

During the summer of 1925, all outstanding design questions were finally settled, and I therefore propose at this stage to give a more detailed description of the main features of the aeroplane, which I have called the Pterodactyl, on account of its supposed resemblance to the prehistoric lizards of that breed.

(i.) *Main Plane.*—The wing section is based on that known as Airscrew 4 of R. & M. 322. In the original design the section was actually Airscrew 4 at the point at which the struts are attached, and the ordinates of all other sections were proportional to those of Airscrew 4, and were reduced to 0.7 times the Airscrew 4 values both at the outer ends of the fixed part of the wing, and at the centre section, which has a constant profile. As the result of wind channel tests, the trailing edge of the section was reflexed up at all points by 0.015 chords, and the top camber reduced somewhat towards the wing tips.

The sweep back of the leading edge of the main plane is 31°, and that of the trailing edge is 15°. The wash-out of incidence is 3° at the strut attachment, increasing by a further 3° to the tip. There is no dihedral angle.

(ii.) *Controllers.*—The section of the controllers is that of T.P. 3, except near the extreme tips, where it is reduced to a thin edge. The controllers are fitted with lead balance weights on forwardly projecting arms to secure a static balance about their hinge; this is done to avoid the possibility of unstable oscillation in flight. These balance weights can be reduced in size and possibly abolished, but it is not known how far it is safe to carry this reduction.

A variable gear ratio is employed between the stick and the controller, so as to obtain a low gear when flying at high speed, and vice versa. Fig. 7 shows the variation of gear ratio with controller angle, from which it may be seen that at the low speed end of the range the ratio is about seven times as high as at the extreme high speed end.

(iii.) *Air-brake.*—The object of the air-brake is not to be able to fly slower, but to glide at a steeper angle without gain in speed. The air-brakes which have been tried in the past have failed for one or more of the following three reasons: (*a*) the air-brake was not powerful enough to have appreciable effect; (*b*) when the air-brake was " on," it interfered with the effectiveness of the other controls; (*c*) it was arranged so that it could be inadvertently left " on," with the result that accidents occurred when the brake was used for gliding into land,

and the pilot changed his mind at the last minute and attempted to make another circuit without taking the brake off.

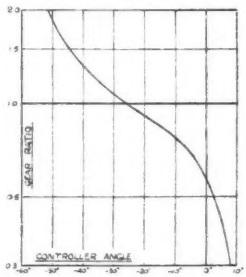


FIG. 7.
Pterodactyl.
Gear Ratio of Longitudinal Control.

The air-brake on the Pterodactyl is formed by the operation of both rudders simultaneously; according to the wind channel tests this is sufficient to double the resistance of the aeroplane, or in other words the glide is twice as steep with the brakes on as with them off. A special arrangement is made so that when both rudders are "on" as an air-brake, the rudder control is not lost. It works in the following manner—when the pilot wants to turn to port, say, he pushes the rudder-bar over with his left foot; when the air-brake is "off" this action brings the port rudder across, but leaves the starboard rudder trailing; when the brakes are "on," the same foot action reduces the angle of the starboard rudder while hardly altering the port rudder, with the result that the aeroplane turns in the same direction as before.

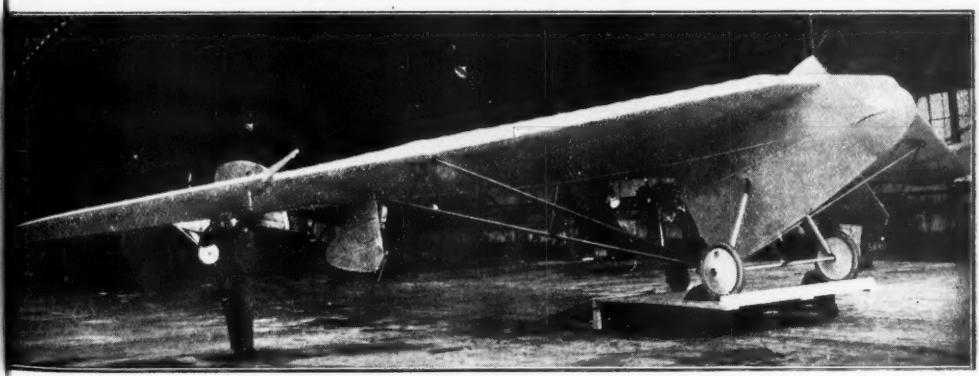


FIG. 8.
Three-quarter View.

(iv.) *Body.*—The body of this type of aeroplane can be made lighter than the standard body, since the forces on it are quite small; the large bending moments due to the tail-plane and tail-skid are avoided. The Pterodactyl body is built up with a special light balsa ply-wood, which weighs only half as much as the standard birch ply.

The engine mounting consists of four steel tubes with ball and socket end fittings braced with tie-rods. It weighs only $3\frac{1}{2}$lbs., and has made a good, simple and rigid mounting, and no trouble has been experienced with it.

A spring steel tube is fitted round inside the nose cowling, so that it may prevent the pilot's feet from taking the whole weight of the machine should it stand on its nose.

(v.) *Undercarriage*.—The front undercarriage consists of two wheels on a common axle, and two legs passing through holes to the inside of the body, where they are anchored with shock-absorber. The legs are braced fore and aft and laterally by four wires.

The rear undercarriage is formed by a single metal wheel in a fork, somewhat after the manner of a bicycle front wheel. Connections are made to the

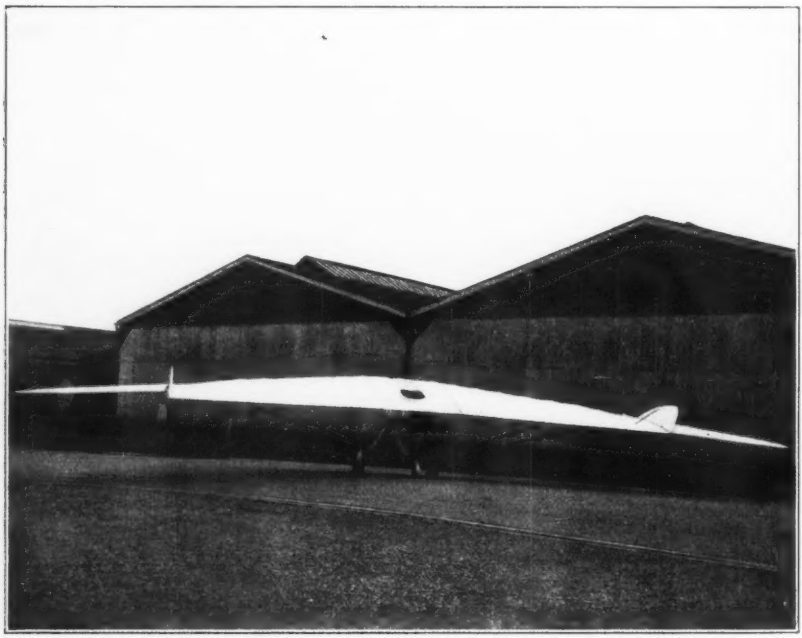


FIG. 9.
Rear View.

rudder-bar for steering on the ground, and a locking device is fitted to the wheel so that it may act as a brake when landing. Since about one-third of the weight of the aeroplane is on this wheel, instead of the usual one-sixth to one-tenth which is carried by the tail-skid, a quicker pull-up when landing is assured.

(vi.) *Trimming Gear*.—In place of the usual tail-adjusting gear, a spring device is fitted to provide any desired force on the stick in the range +15 to −15lbs. This gear does not suffer from the well-known disadvantage of the simple spring, which makes the controls much heavier to work, as it is fitted with my patent "constant force" spring, which provides the same reaction whatever the position of the stick. The total weight of the gear is 5lbs.

(vii.) *Controls.*—The normal controls, *i.e.*, stick and rudder-bar working in the normal way, are fitted. In addition, there are levers working the trimming gear and ground brake, and a handle for the air-brake. This handle, worked, as is the throttle, with the left hand, has no ratchet arrangement, so that it cannot inadvertently be left "on," and the throttle opened with the idea of resuming level flight or climbing again.

The engine controls consist of switch, throttle, and petrol tap which controls the flow from a gravity tank to the engine. The magneto advance is interconnected with the throttle, so that it is fully retarded when the throttle is closed, and fully advanced when the throttle is between one quarter and full open. No altitude control is at present fitted.

7 *Flight Under Power*

When the construction was nearly complete, I was allowed to take my men over and erect the aeroplane in the R.A.E. with a view to flying it on the aerodrome at Farnborough. The finishing touches dragged on as they always seem to do until October 28th, when I carried out a taxying test on the aero-

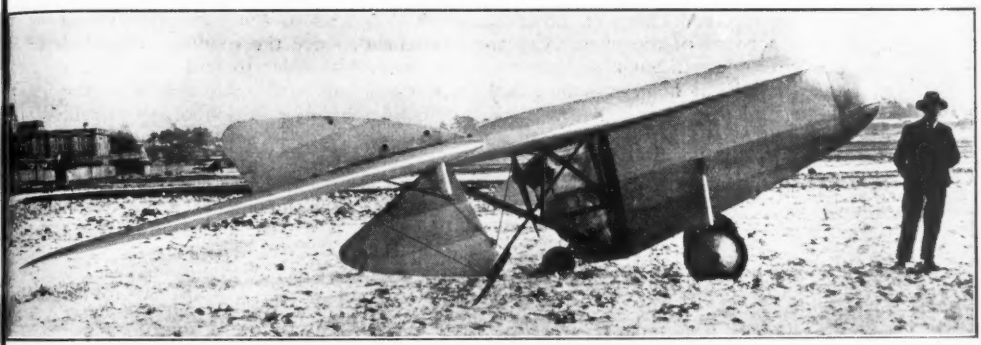


FIG. 10.
Side View.

drome; as the result of this test more shock-absorber was fitted to the back wheel.

November 2nd saw the first flight under power, and a slow motion picture of this was taken; I thought it might help to throw light on the cause, should an accident have happened when starting or landing. This flight was made under comparatively bad weather conditions and lasted about five minutes; the wind was blowing at about 15 m.p.h. I deliberately chose a day like this, as I was still worried about the possibility of the short undercarriage misbehaving itself; though I knew the aeroplane would be unpleasant in the bumps, yet I felt quite certain in my own mind that it would be quite controllable, and I thought it safer to get off the ground at once and avoid anything in the nature of an increasing oscillation, which I was afraid might be produced by a long run over ground which was none too smooth for my smallish wheels. However, again all my fears were groundless, and I was able to take off and land without the slightest difficulty.

On the third flight I carried a parachute stowed on the decking behind my head; this was the first flight on which I attempted anything in the way of stalling. There was no reason to suppose that stalling would cause either a

loss of control or a structural failure, but in this kind of experimental work I believe in taking every precaution that possibly can be taken. Fortunately I was able to make a safe landing without having recourse to the parachute, which as a matter of fact I do not normally carry, as in the narrow cockpit the harness is uncomfortably cramping.

8 *Results of the Flight Tests*

Twenty-one flights have now been made, and I propose to group the information obtained during those flights under the headings Performance, Trim, Stability, Steadiness, Control, and Taking Off, Landing and Taxying.

(i.) *Performance.*—The top speed of the aeroplane at ground level has been determined by timing over the lower speed course at Farnborough. With a total load of 658 lbs., wing loading 2.95 lbs./ft.^{2}, the speed was 70 m.p.h. with the engine r.p.m. of 3,440. The speed with a passenger would be within a mile an hour of this figure.

An attempt has been made to measure the stalling speed by observation of the minimum reading of the air speed indicator. There is no disagreement on this point, as Squadron Leader Haig gives the value 24 m.p.h. and I have recorded 25 m.p.h. There is, however, some doubt as to the correction to be applied on account of the position of the Pitot head, since the readings recorded above were made without a suspended static head. In order to find this correction, a model Pitot head was mounted on the existing 1/16 scale model of the aeroplane, and it was found in the wind channel that an addition of 4½ m.p.h. was required to obtain the minimum speed from the flight observations. If this is correct, the stalling speed of the Pterodactyl is about 29 m.p.h., as compared with 31½ m.p.h. as calculated from the maximum lift coefficient measured on the model. A suspended static tube is being fitted to the aeroplane so as to check the accuracy of these figures.

(ii.) *Trim.*—(*a*) *Longitudinal.*—By adjusting the spring trimming gear the aeroplane can be flown "hand off" at any speed. There is a slight change of trim engine on and off at the higher speeds, but nothing appreciable at the lower speeds. The change of trim when the air-brakes are operated is negligible.

(*b*) *Lateral.*—If the aeroplane flies one wing down, it can be corrected by altering the length of one of the rear main bracing struts, which are fitted with adjustable ends for this purpose. This is of course a ground adjustment.

(*c*) *Directional.*—The aeroplane shows no turning tendency with engine either on or off.

(iii.) *Stability.*—(*a*) *Longitudinal.*—The aeroplane is longitudinally stable with controllers free throughout its whole speed range. No means of locking the stick or controllers has yet been provided, but there is no reason to suppose that the stability with controllers fixed is unsatisfactory. The aeroplane has a relatively quick period of oscillation; at 40 m.p.h. I made a rough measurement of nine seconds for the period; the damping seemed rather less than usual. Further measurements on this point will be made shortly.

(*b*) *Lateral.*—The aeroplane is stable laterally at all speeds. If the stick is let go when sideslipping, it immediately returns to the centre, and the aeroplane assumes a level keel; at 40 m.p.h. I observed a quick heavily damped lateral oscillation of about four seconds period. The aeroplane will fly with feet off the rudder bar, and if the rudder bar is kicked over and released, it returns to the central position, and the aeroplane resumes its steady straight flight.

(iv.) *Steadiness.*—The aeroplane is sensitive to bumps owing to its very light wing loading, and is affected noticeably more in the fore and aft plane than laterally; this may be explained by pointing to the fact that the tailless type

is a small aeroplane fore and aft and a large one laterally. My first impression is that the aeroplane feels the bumps much less when stalled than when in normal flight; there are, however, theoretical grounds for believing that this may be so.

(v.) *Control.*—(*a*) *Inertia Effect.*—Perhaps the most noticeable, and certainly the least satisfactory, feature of the controls operated by the stick is the excessive amount of inertia which exists in the system; this inertia is equivalent to a weight of about 75 lbs. on the top of the stick, and it is easy to realise how the effect of this will tend to mask the "aerodynamic" feel of the controls when manœuvring. The first impression it gives is that the fore and aft control is just overbalanced. This of course is not so, since the aeroplane will fly "hands off"; but there is no doubt that it makes the control tricky, different from what one is used to and unpleasant at first in bumps. It is most important to try and separate the part played on the feel of the control by inertia from that played by the aerodynamic forces. The reason for this is that the inertia effect is peculiar to this actual machine only, and may be reduced to a small fraction of its present importance on a production type; this will be effected by lowering the gear ratio between stick and controller, by reducing the controller area and by reducing the inertia of the balance weight.

(*b*) *Longitudinal.*—Apart from the inertia effect, the fore and aft control is sensitive, powerful and reasonably light. It is particularly light on steep turns, when very little pull is required to prevent excessive speed. I have done turns banked to about 45° on the rudder alone, and the speed increases from say 40 m.p.h. flying straight to 50 m.p.h. on the bank, without touching the stick; this increase in speed is just about what is required to keep the incidence constant.

FIG. 11.
A Stalled Glide.

There is no definite stalling "point," though there is a definite minimum speed. If the engine is throttled down, the aeroplane will glide at say 40 m.p.h. with the wing chord roughly horizontal; if the stick is now pulled slowly back, the speed decreases and the true angle of descent increases, but the aeroplane still maintains the same attitude to the horizon. After the minimum speed is reached, the more the stick is pulled back the faster the aeroplane sinks; under these conditions it may be said to be stalled, in that the angle of incidence is greater than the critical angle, but it is nevertheless under good control, even in bumps.

One of the most interesting points which I have observed with regard to this stalled flight is that it is possible to transform the stalled flight to unstalled flight without any kind of dive to gain speed. If when stalled, the stick is gradually eased forwards, the attitude of the aeroplane to the horizon hardly changes, and all that happens is that the speed of descent is reduced to the normal rate of height loss when gliding. This feature is evidently of great value in the case of an accidental stall near the ground.

(*c*) *Lateral.*—Apart from the inertia effect, which, owing to the lower gear ratio of the lateral control, is less felt than on the fore and aft control, the

FIG. 12.

Coming in to Land with Air-brake "on."

lateral control is normal. It is reasonably light, in spite of the large area of the controllers, and banks the aeroplane over quickly for a machine of 45 ft. span. It is probable that the aeroplane manœuvres more nearly like a normal type of 30 ft. span, which is the span of the fixed part of the wing only.

When stalled the control is effective, though sluggish owing to the low speed through the air; it has none of the sloppy feel of the normal ailerons when stalled, but continues to "bite" the air.

(*d*) *Directional.*—The rudder control in normal flight differs more from the standard than either of the other controls. If the rudder bar is pushed over in straight flight, the turning effect produced is surprisingly small, yet when manœuvring there is no lack of rudder power; the reason why this should be

so needs elucidation, but other pilots who have flown the aeroplane agree with me in the description of the effect described above.

I have noticed that on turns, and particularly on steep turns, the rudder has to be held on during the turn, and the steeper the turn the more is the rudder required. This feature indicates a more straightforward control than the normal, in which it is necessary to reverse the rudder on a steep turn to prevent the nose from going down.

In stalled flight the rudder control appears quite adequate to maintain direction and carry out gentle turns even in bumpy weather.

A difficulty encountered with the rudder control arose from the idea that the rudders when left to themselves would lie along wind and parallel to each other. They appear to lie along wind, but the direction of airflow (*i.e.*, relative wind) under the wing is inclined outwards to a surprising degree, with the result that the rudders in flight lie with their trailing edges out, thus causing both control wires to fall slack.

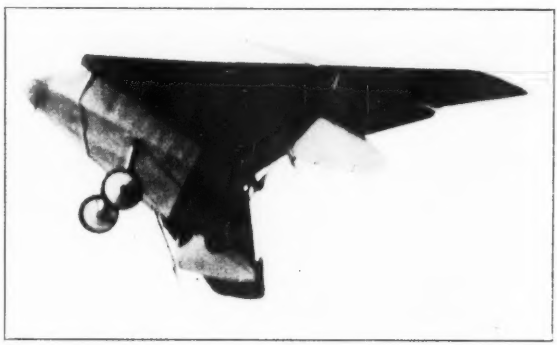


FIG. 13.
Taking Off.

Some model experiments were made to explore the outward flow under the wing, and revealed angles of flow varying between 3° at top speed to 15° at stalling angle. The rudders have now been rigged out so that they always lie at an angle of 7° to the line of flight, but this still leaves an excessive amount of slack in the control wires at slow speed.

(*e*) *Air-brake.*—When the handle for operating the air-brake is pulled, the aeroplane immediately slows up, and the nose must be dropped to maintain speed; the inherent stability of the aeroplane will do this if the stick is not touched. When the brake is "on," the aeroplane glides comparatively steeply at 40 m.p.h., the speed at which I usually approach the aerodrome to land. It becomes a very simple matter to judge the approach; the engine may be shut off anywhere in the large region from which a straight glide with air-brake "off" would overshoot, and with air-brake "on" would fail to reach the landing point; during the glide the air-brake is then manipulated so that the gliding angle is such as to bring the aeroplane at the right speed to the selected spot. The worst pilot can then judge his approach as successfully as the best.

The pull required to hold the brake on is always noticeable, and there is no danger of flying with the brake "on" without being continuously aware of the fact.

(*f*) *Taking Off, Landing and Taxying.*—There seems to be a period during the take off, as was foreseen in my first report, in which the directional control is weak. Since there is no slipstream over the controllers, the aeroplane runs along on all three wheels until shortly before it rises; as it picks up speed, the controlling power of the steering back wheel falls away rapidly as the weight on the wheel is reduced; the rudder power below the speed of take off is weak, and on one occasion the aeroplane swung badly while taking off. Apart from

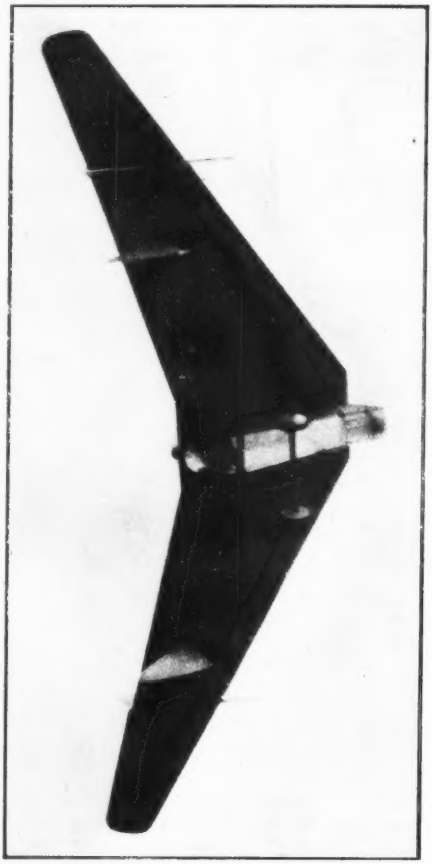


FIG. 14.
On a Turn.

this single instance, no difficulty in taking off has been experienced, though there obviously is a period during which movements of the rudder-bar have little effect.

Landing is extremely easy, owing among other factors to the excellent view forwards, the slow speed, and the cushioning effect of the ground. It seems almost impossible to make a bad landing. If the ground brake is put on when coming in to land, the back wheel acts like a skid, and the run after landing is remarkably short.

The aeroplane steers well when taxying, and can be turned with the steering back wheel about its wing-tip. The short fore and aft length (five feet) of the undercarriage has not proved nearly so troublesome as it looks; the front axle has the same relation to the centre of gravity as on the standard Bristol Fighter, so that when the back wheel is off the ground, the Pterodactyl is no different from the normal. When taxying on rough ground, however, pitching or bucketting is more pronounced, owing to the short wheel base. The pilot, owing to his position far in front of the wheels, feels the motion acutely, and fears that the aeroplane is in imminent danger of overturning, when to observers on the ground little motion is apparent. After a few flights one gets used to the feel, and there should be no real danger from this source.

9 *Conclusions*

I consider that, when the inertia of the control system has been reduced to reasonable proportions, the control of the Pterodactyl will be an improvement on anything we have at present.

Each of the four controls performs its own function and does not interfere with any of the other controls. Variation in engine power has no effect other than an alteration of the rate of climb or glide.

On turns, both the fore and aft and rudder controls are more straightforward and simple in operation than on the normal aeroplane.

There is no stalling "point" or marked division between stalled and normal flight; the pilot can "unstall" without increasing his rate of descent.

In general, the aeroplane is always under good control up to large incidences, which are in the neighbourhood of 45°. I therefore believe that I have attained, without loss of performance, the objective towards which I set out over three years ago.

But this is by no means the whole story. There follow, in addition, three aerodynamic advantages which I think may be said to be inherent in the type:—

(i.) The tailless design can be built for a percentage structure weight smaller than the normal.

(ii.) It is once more possible to revert to the pusher type without loss of performance.

(iii.) An improvement can be made in the general arrangement of the flying boat.

Although my experiments started with entirely peaceful aims, I cannot wind up without a reference to the warlike advantages of the tailless aeroplane, which are obvious alike to Service officers and laymen.

10 *The Future*

And what of the future? The first step is to prove that the ideas I have demonstrated on the "light aeroplane" will work equally well on a larger scale and may be applied to the biplane form. The next step will be to try out a re-arrangement of the design, which I believe will result in a considerable reduction of head resistance. But what I think to be really encouraging is that while normal design is moving but slowly through the bog of convention, the ideas on which I have been working form an avenue of escape from natural limits which press so close on every hand.

APPENDIX

SUMMARY OF WEIGHTS, WING AREA, ETC., OF THE PTERODACTYL.

DIMENSIONS.

Area of main plane	223 sq. ft.
Wing span, overall	45 ft.
,, fixed part of wing only	30 ft.
Area of controllers	55 sq. ft.
,, rudders	13 sq. ft.

WEIGHTS.

	lbs.	With large wheels. lbs.	With small wheels. lbs.
Weight empty	—	458	444
Weight of petrol and oil	30	—	—
,, pilot	170	—	—
Total weight, single-seater	—	658	644
Weight of passenger	170	—	—
Total weight, two-seater	—	828	814

LOADING.

Lbs. per sq. ft., single-seater	2.9
,, ,, two-seater	3·7
Lbs. per h.p., single-seater	20
,, ,, two-seater	25

NOTE.—I am indebted to the Air Ministry for permission to publish information respecting the tailless aeroplane which has been obtained at the R.A.E., but which has not yet been published.

DISCUSSION

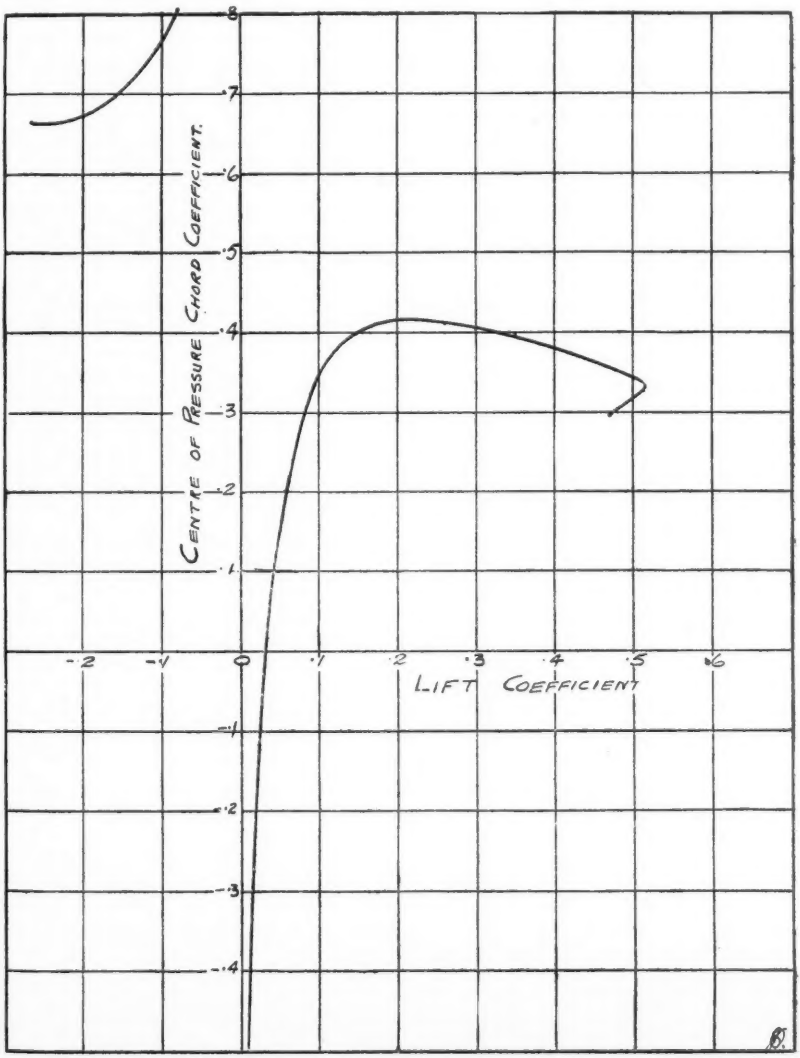
In opening the discussion, General Brancker said: We not only have to congratulate Captain Hill most heartily on his magnificent achievement, but also on having given us one of the most interesting papers that I have heard read before this Society. In opening the discussion, I would like to ask Captain Hill two or three simple questions. Captain Hill's machine is extremely lightly loaded. Now, I have always said that the B.E. 2c. with 70 h.p. Renault engine, which was flying in 1914, was the most stable aeroplane that I had ever seen, and that we had never since attained the same standard in newer designs. Certain experts have replied to me that the B.E. 2c. was a very lightly loaded machine and that it was impossible to get the same stability with the heavily loaded commercial machines of to-day. I would like to ask Captain Hill, therefore, what result he thinks an increase of load to 9 or 10lbs. per square foot would have on the stability of his tailless machine?

Captain Hill said that he did not know of any other aeroplane which would fly stably with all the controls released. Just to prevent Captain Hill becoming lazy or tending to vegetate, I must tell him that about six weeks ago I flew in an experimental aircraft in America which, so far as I could judge, was absolutely stable. She had dual control, and I sat beside the pilot. For some minutes we let the machine fly with hands and feet off all controls, and she behaved perfectly.

I would also like to know whether Captain Hill thinks that he would get a better performance with the engine in the tractor position. It seems possible that his machine may be labouring under the usual disadvantages of a pusher and that actually he has made a bigger stride in performance than has yet been demonstrated.

Mr. F. HANDLEY PAGE said that he had been very interested in the tailless type of machine, and had built both a monoplane in 1911 or 1912, and a biplane in 1913 or 1914 with back swept wings. The wing itself was of rather thick camber, with reflex rear edge in the centre, and had a lesser angle of incidence and a wash-out towards the wing tips, so that the wing itself had the desirable characteristic to which Captain Hill had referred, *i.e.*, the constant centre of pressure. Unfortunately—so Captain Hill would say—he had stuck on a tail, which, it now appeared, had completely nullified the good effects which should have been obtained had the tail not been fitted. The pilot who had operated the

machine had had however strong views on the desirability of control, and it was the pilot, he believed, who had insisted that the machine must be made more or less in accordance with conventional design. He had been reminded by one of his staff that when the biplane was made experiments had been carried out—Flight Lieutenant Whitehouse was the pilot—with the tail plane fabric completely removed, so as to prove whether or not the machine had a constant centre of pressure. His recollection was that the pilot had flown the machine with his hands off the control. It was difficult to remember the details at this date, but he would look up the technical information and communicate them to



the Society in writing. One thing which he had found at that time, however, with a short wheel base between the main wheels of the chassis and the tail skid, was that when there was a fairly heavy load on the tail skid—and the tail skid was not much behind the wheels—there was a tendency for the machine to be unstable on the ground and to spin round in a circle, a tendency which was somewhat similar to that of the Nieuport machine, which had won the French Military Trials in 1912. At the beginning of the war period he had dropped that type of design, and had gone in for what had proved to be a more lucrative type, but his interest in the tailless machine had been by no means diminished, and he would be delighted if Captain Hill could add to the information already published by giving some further aerodynamical data for the help of others who might wish to build small gliders and to experiment privately. Captain Hill's remark, that he believed he was the only individual who had been *helped* by the Air Ministry (laughter) seemed to him to be an extraordinary expression of opinion, and presumably those who were *controlled* by the Air Ministry were still moving slowly through the bog of convention to which reference was made at the end of the paper. He hoped that, if Captain Hill's research had no other effect whatsoever, it would enable the Air Ministry to escape from the morass in which according to Captain Hill it now found itself and to allow the companies it controlled a little more freedom, so that they could move along newer lines.

LIFT AND DRAG COEFFICIENTS, ETC., AS OBTAINED FROM THE N.P.L. TEST REPORT.

Angle of Incidence (Degrees)	K_L	K_D	L/D	Position of C.P.
−6	−.265	.0538	−4.93	+.663 Chord
−4	−.167	.0338	−4.94	+.690
−2	−.079	.0219	−3.6	+.811
0	.013	.0159	.82	−.558
2	.096	.0135	7.10	+.335
4	.175	.0141	12.4	.414
6	.259	.0182	14.21	.412
8	.348	.0254	13.70	.397
10	.422	.0364	11.58	.375
12	.490	.0535	9.17	.351
14	.516	.0715	7.22	.337
16	.512	.0962	5.32	.327
18	.499	.1158	4.31	.318
20	.468	.1360	3.44	.297

Squadron Leader HAIG said it had been his lot to fly the machine at Farnborough for its C. of A., and he had had the pleasure of watching it being built and of discussing it with Captain Hill.

He did not think that anybody could have spent more time, or could have taken more trouble with the machine than Captain Hill had done.

The machine in the air could hardly be called a light aeroplane; the span was too great, it was somewhere about the same as a DH9A.

The control, under normal conditions, was very similar to the control of a very controllable large machine, but when one got down to a stall in Captain Hill's machine, the control was exceptional. There was no doubt that it did not stall in the normal way, and when flying at a large angle of incidence one could control the machine directionally, and roll it and pitch it fore and aft as well, in fact he was prepared to bear out all that Captain Hill had said about the control of the machine in the air.

There was one point with regard to landing which Captain Hill had not mentioned, and that was the position of the pilot's seat in relation to the

undercarriage; when landing, the pilot felt that the machine was about to turn over, and therefore he was inclined to pull the stick right back, thereby pulling the controllers up well above the stalling angle. While this was amusing to watch, it was of very little use.

Professor MELVILL JONES, in congratulating Captain Hill upon his achievement, said it had quite possibly initated a new epoch in flying. Captain Hill's work had shown that, in spite of the movement towards group research largely controlled by the Government, it was still possible for a sufficiently determined man to secure sufficient help to enable him to carry out independent research. It might be difficult for most people to imagine the very great degree of determination which must have been necessary in order to carry out this work to a successful conclusion. On the technical side, the main point in Captain Hill's design, as he saw it, was that it had achieved control in a stall in an extremely convenient way. He believed that control of that order could eventually be achieved with the more conventional type of machine, but possibly at the expense of rather heavy and somewhat elaborate control organs. Captain Hill had achieved a remarkable result in a workmanlike manner, and in a manner which, on the face of it, looked reasonable. But in addition to that great advance, there were several minor achievements which were also of great value. The mere fact that Captain Hill had produced a machine by means of which there was every indication of the pusher being made efficient was in itself sufficient to call together a large and enthusiastic audience. Again, the fact that he had found a convenient way of using air brakes to alter the angle of glide when flying in to land was of immense importance. The power to alter the gliding angle would enable the large passenger aeroplane of the future to be brought to ground in a long straight glide on an even keel, without resorting to terrifying stunts for the purpose of losing height or to an engine (which may be unreliable) to prolong the glide.

Mr. MACKINNON WOOD, who was asked by the Chairman to compare the control on Captain Hill's machine with the slot and aileron control from the point of view of stability, said he considered that Captain Hill's aeroplane had one great advantage over the aeroplane with the slot and aileron control. In the slot and aileron control one had got rid of the objectionable and weak features of the ordinary ailerons, and had provided ailerons which retained their full effectiveness when the aeroplane was stalled, but one had done nothing to stop the aeroplane of itself passing into a spin when it was stalled. Nothing had been done to check rotation, whereas in Captain Hill's aeroplane one had surfaces at a very fine angle to the wind at the wing tips, and he had so proportioned his aeroplane, according to the wind channel tests, that it had no tendency to auto-rotate. He now believed, as the result of experience at the R.A.E., that the provision of really effective control constituted nine-tenths of the battle. He used to think that it might prove necessary not only to provide effective control, but to stop the tendency of the aeroplane to go into a spin when stalled. It was very valuable to get out of a rut, and certainly Captain Hill's aeroplane opened up new vistas in aeroplane design which might enable us to secure other advantages, but it was this feature of the aeroplane, its safety in slow-speed flight, which appealed to him particularly. The importance of control at low speeds had been fairly fully realised in this country, certainly by the Aeronautical Research Committee and by those who had been doing research in Government establishments; but he believed that in no other country had much attention been paid to it, and it was a matter upon which we could congratulate ourselves. Although a great deal of research had been devoted to this problem, however, he was not sure whether the users of aeroplanes quite realised its importance. He had had the opportunity of learning the views of a number of pilots, and he found them inclined to believe that they

never would accidentally stall. Recently, in reading aeronautical journals, he had noticed a reference to an experienced pilot who, at the end of a tiring flight, had stalled the aeroplane on a turn and had lost his life; such accidents were not confined to novices. It was difficult for pilots to realise that they might be up against this danger. In congratulating Captain Hill upon a very notable achievement, he said that whether or not it would be a landmark in the history of aviation he would not like to prophesy, but it was certainly a very strong candidate for that position.

Major H. E. WIMPERIS, after thanking Captain Hill for his paper, said that the Society had now had described at its meetings several methods of increasing the safety of flight by avoiding the loss of control which arose when near stalling. There were the slot and aileron control, the rotating wing, and the tailless aeroplane built by Captain Hill. Which of them would in the end prove to be the best solution remained to be seen. Naturally, the Air Ministry was exceedingly interested in all of them, and he felt sure that the Society would like to know what the Air Ministry was likely to do in regard to the development of the tailless machine. It was proposed to endeavour to obtain possession of Captain Hill's original machine, and to continue research on it, if possible with Captain Hill's assistance. In addition, it was proposed to build one or two larger machines of the same type. With regard to Mr. Handley Page's comment on the suggestion that Captain Hill was the only individual whom the Air Ministry had ever helped, probably Mr. Handley Page would not regard that as entirely equitable, but perhaps in the distant future the day would come when everybody would be pleased: when there would be fulfilled the words of the psalmist, "The Mountains skipped like rams, and the little Hills like young sheep."

Mr. C. G. GREY asked if Captain Hill had any knowledge of the work done by the late Mr. José Weiss in 1908 and 1909. Weiss had a perfectly good tailless aeroplane, on which Squadron Leader England's brother had glided a distance of something like 1½ miles from the top of Amberley Mount, in Sussex, proving that it was quite controllable, both fore and aft and sideways. Weiss, however, had not the money to develop it properly nor had he the seventeen years of mechanical experience, which we had had since then, with which to construct his machines. He would like to know how those machines, and also the Austrian Etrich, which was built at about the same date, differed from Captain Hill's machine aerodynamically. Mr. Handley Page could say a good deal about the Weiss machines if required.

Wing Commander MAUND suggested that washing out the angle of incidence from root to tip of the wings to obtain a constant centre of pressure must result in some loss of aerodynamic efficiency, and said he thought, from his own investigations of the question of tailless aircraft, that other means, such as varying the wing section from root to tip, and the use of wing sections having a nearly stationary centre of pressure would obviate this sacrifice.

One of the great drawbacks to the more general use of the monoplane is the structural weight necessary to resist torsional stresses; back swept wings can be made naturally rigid torsionally, and so save weight.

Captain HILL replied to the discussion. Dealing with the Chairman's question as to whether the machine would work as well with a heavier loading as with a light loading, he said that that was just what he wanted to find out, and was hoping that the Air Ministry would be able to help in that connection. He had been very interested to hear of the American machine which was so stable, and would like further details of it. He would do his best not to be beaten in this respect, anyhow. It was his intention to carry out experiments as to the comparative efficiency of the pusher and the tractor engine at the earliest possible opportunity, and he proposed to carry out the experiments on

the machine he had made, simply by taking the engine off the back and putting it on the front. There should not be any very great difference in efficiency as between the two positions, although he thought that probably the efficiency would be greater if the screw were behind rather than in front.

He remembered quite well the machine with the back swept wings, which had been mentioned by Mr. Handley Page. The experiments had been described in " Flight," and when removing the fabric from the tail, he did not think that Mr. Handley Page had gone far enough; a little more boldness with his pen-knife, and he might perhaps have arrived fourteen years ago where he (Captain Hill) stood now. He would also like to commend to the attention of Mr. Handley Page his (Captain Hill's) system of works organisation, which entirely avoided the imperfect co-operation between pilot and designer of which Mr. Handley Page had spoken. With regard to the spinning of the machine when on the ground, he had experienced no difficulty about that with his machine. On one occasion the machine had swung when getting off the ground, but there had been no difficulty with regard to steering when actually on the ground. The steering back wheel was connected with the rudder bar, and when the pilot moved it with his feet he could steer very well when on the ground.

As to the apparent danger of turning over when landing, as mentioned by Squadron Leader Haig, he agreed that it did feel very uncomfortable as he had mentioned in the written paper, though he did not think there was danger, and he had gradually got used to it. On the occasion of his first landing with the machine he had thought the end had come, but had since got hardened to the bucketting.

With regard to the size of the controllers, as mentioned by Professor Jones, he said he hoped to be able to cut them down considerably; in fact, to something like half their present size. That, in his view, was really the most important of the experiments which must be carried out, because on a heavier machine the controllers would certainly be very large. This should, he thought, not be remedied by cutting off the tip, but by keeping the overall shape of the wing and controller about the same, and altering the division between wing and controller. He had made them of very large size to start with, because it was so much easier to cut them down than to increase them. Their area was a quarter of the wing area.

Referring to Mr. MacKinnon Wood's comparison of the control on the " Pterodactyl " and the slot and aileron control, he said that when referring to conventional design in the paper he had excluded such ideas as that; he had, unfortunately, not had the opportunity of flying a machine with slot and aileron control, and so could not make a comparison from first-hand knowledge. He agreed that control was the most important, but stability, in his view, was by no means a negligible factor. His own system combined good lateral control with fore and aft control, with a very much greater range than is ordinarily the case. That could be secured by an " all-moving " tail as used for instance on the old Morane, but at the same time, in order to do on the normal aeroplane the things that he had been able to do on his machine, one would have to fit first one extra and then another, and by the time one had done that one found oneself in trouble through extra weight and the number of extra parts.

He remembered the Weiss monoplane quite well, and had tried to get some slides of it. He seemed to remember, from the pictures he had seen of that machine, that there was no lateral control at all; it had good stability, and relied on that entirely. He believed that Weiss had an elevator and a rudder, but no method of banking the machine. At the present stage we needed something more than inherent stability; we wanted control as well as stability, and he thought that he had got both. He would like to make it clear that he did not claim any novelty in the use of the swept back tapered wing, washed out in

incidence towards the tips, which had of course been used at various times for many years; but he wished to point out that it was his system on control and disposition of control surfaces which he believed to differ fundamentally from any type proposed or used in the past.

Replying to Wing Commander Maund on the question of wash-out of incidence and loss of aerodynamical efficiency, he said it was stated in the paper that when he had designed the wing section we did not know so much as we did now about sections like the R.A.F 30 or the American M 12, which, practically speaking, had stationary centres of pressure. It was obviously better to use sections of that sort, because we could avoid wash-out almost entirely, and, incidentally, could get over the difficulty of torsion on the monoplane wing structure. He had been afraid of torsion, and had put large and long struts underneath the wings, stretching well out along the span, for the sake of rigidity, although weight was lost by so doing.

Perhaps it was wrong to say that he was the only person who had had assistance, as an individual, from the Air Ministry, but he was certainly the only person he knew who had received assistance in the kind of experimentation on which he had been engaged. Some of the speakers seemed to think that there was some value in assistance being given partially, and on a very small scale, but he could not quite agree with that (laughter).

The CHAIRMAN, proposing a vote of thanks to Captain Hill for his paper, said that his achievement looked like being a landmark in the progress of aviation. From the civil aviation point of view it looked like being a really valuable advance, because it would enable us to fly more safely and more regularly. Air transport to-day had reached a point from which nearly all future progress depended upon improved design, research and technical development generally, and he felt that Captain Hill had made a real step forward. It was really refreshing to meet someone who had managed to drag himself out of the bog of conventional design, and he implored designers not to wait for the assistance which Major Wimperis was promising, but to go ahead without being spoon-fed by the Air Ministry. Finally, he said he could not speak too highly of Captain Hill's courage and enterprise, and congratulated him most heartily upon his great achievement.

The vote of thanks was accorded with acclamation, and the meeting closed.